TM 10-560

WAR DEPARTMENT

TECHNICAL MANUAL

CHASSIS, BODY, AND TRAILER UNITS

May 20, 1941

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TECHNICAL MANUAL

CHASSIS, BODY, AND TRAILER UNITS

CHANGES No. 1 } WAR DEPARTMENT, WASHINGTON, January 27, 1942.

TM 10-560, May 20, 1941, is changed as follows:

6. Plan.

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b. A frame with straight parallel side members is easier to manufacture and has more resistance to vertical bending resulting from the load. Since many military and commercial trucks are subjected to heavy loads, truck frames are usually made with straight parallel side members (fig. 3).

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[A. G. 062.11 (12-19-41).] (C 1, Jan. 27, 1942.)

7. Cross members.

* * * * * * *

b. Another cross member is generally found near the front support for the rear spring. This provides a firm support for the spring connection and stiffens the frame at this point. The frame must be firm here because the vehicle is driven or pushed through this connection, **when, as is usual, the** Hotchkiss drive is used. Rear cross members furnish supports for the fuel tank, rear trunk, etc.

* * * * * * *

[A. G. 062.11 (12-19-41).] (C 1, Jan. 27, 1942.)

31. Heavy vehicle suspension.

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c. Two rear axles are used on numerous heavy vehicles to decrease the load on each rear wheel, to decrease the effect of road shocks, and to increase traction. A typical rear end on 6-wheel vehicles (fig. 26) consists of an axle mounted on each end of the rear springs, with the load of the vehicle applied at the center of the spring by means of a spring seat supported on the frame. **The drive is applied to both axles.** Torque rods apply the driving force to the frame and are usually arranged to relieve the springs of any torque reaction. The rear springs carry the same load they do with a single rear axle, but the load is distributed over two axles instead of one.

[A. G. 062.11 (12-19-41).] (C 1, Jan. 27, 1942.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff

OFFICIAL:
E. S. ADAMS,
Major General,
The Adjutant General.

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WAR DEPARTMENT,
WASHINGTON, May 20, 1941.

CHASSIS, BODY, AND TRAILER UNITS

Prepared under direction of
The Quartermaster General

SECTION I

GENERAL

1. Groups.—A motor vehicle is divided into two general groups: the chassis and the body. The chassis group includes all the units necessary for the proper operation of a motor vehicle. The body provides accommodation for the passengers or the load which the vehicle is intended to carry. A motor vehicle can transport loads in addition to those carried in the body by towing a trailer.

2. Classification.—*a. Chassis.*—(1) A chassis (fig. 1) includes all the units composing the engine and its necessary accessories, the power transmission system, the suspension system, the steering system, the braking system, and the axles and the wheels. These units are all attached to a frame which serves as a structural center for the chassis and as a foundation for the entire vehicle. The engine and its accessories, the power transmission units, the brakes, and the driv-

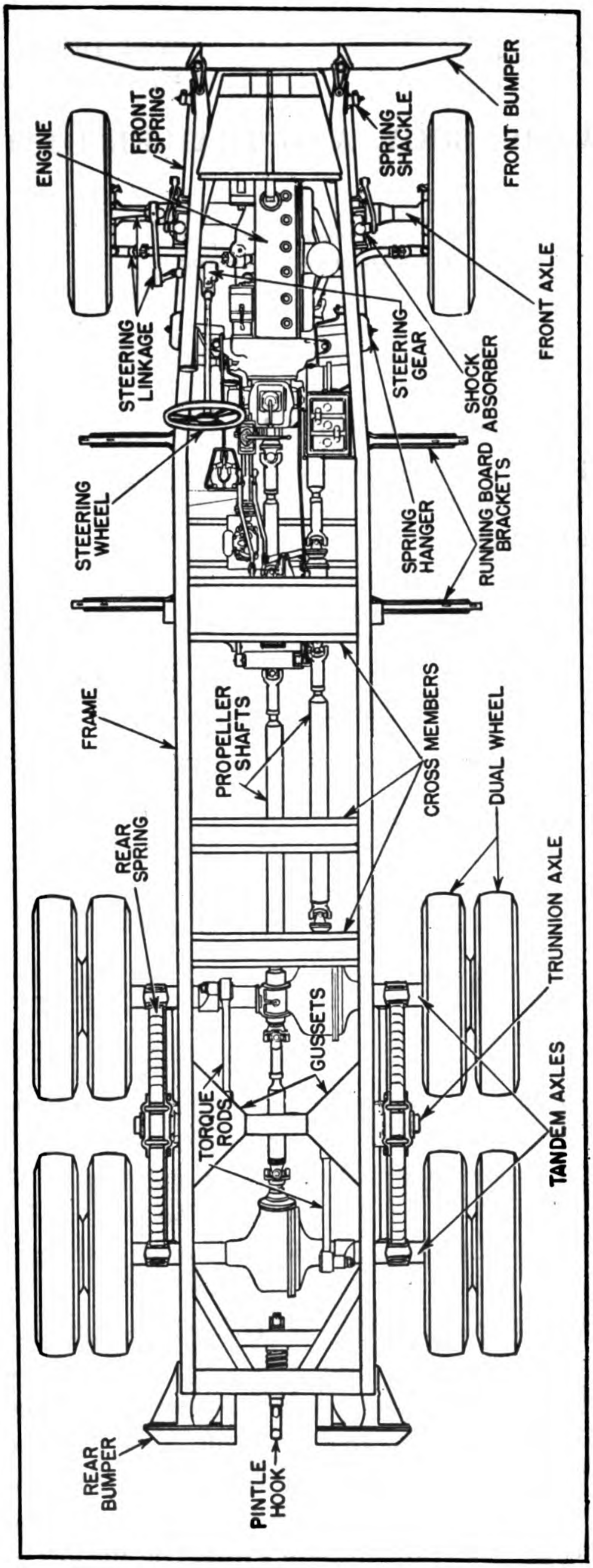

FIGURE 1.—Chassis of a 6-wheel truck.

ing (or live) axles are described in other Technical Manuals. All other chassis units are described in this manual.

(2) The frame is supported on the axles and wheels through a suspension system which allows the wheels to move up and down without unduly straining the frame. The steering system turns the wheels (usually the front wheels only) to control the vehicle's direction.

b. Body.—The body of a motor vehicle is mounted on and directly supported by the frame. Accommodations are provided for the operator and passengers or for the load carried by the vehicle. On trucks, a cab or compartment separate from the pay-load compartment provides accommodation for the operator and contains all the necessary controls and a panel for the vehicle's operating instruments. Body types and their construction are discussed in section VIII.

c. Trailer.—The function of a trailer is to carry loads. The methods of pulling a trailer and trailer construction are discussed in section IX.

3. Terminology.

Axis.—A center line; a line about which something rotates or about which it is evenly arranged.

Axle.—A cross support on a vehicle on or with which its wheel or wheels turn. Live axles while carrying the vehicle load also transmit power to the wheels. Dead axles transmit no power to the wheels.

Bending moment.—The tendency of a moment (force at a distance from the supporting point) to bend or distort a beam.

Body.—Structure mounted on a vehicle chassis to provide accommodation for the operator, passengers, and cargo.

Bogie.—A suspension unit consisting of tandem axles joined by a single cross support (trunnion axle) that also acts as a vertical pivot for the entire unit.

Bond.—To bind together.

Cab.—Separate driver's compartment provided on trucks.

Camber.—To curve or bend; the amount in inches or degrees that the front wheels of an automotive vehicle are tilted in or out from a true vertical at the top. Motorcycles do not have camber.

Caster.—The amount in degrees that the steering knuckle pivots are tilted forward or backward from a true vertical.

Center of gravity.—An imaginary point within the length and width of a vehicle about which all the vehicle weight is balanced.

Chassis.—The framework of a vehicle including all the parts necessary for its operation.

Cowl.—The front portion of the body or cab which partially encloses the dash panel and forms the windshield frame.

Dash panel.—The partition which separates the engine compartment from the driver's compartment.

Distortion.—A twisting or writhing motion; or twisted or misshapen condition.

Dolly.—A 2-wheel trailer-truck coupled to a semitrailer to support and steer its front end when it is converted into a full trailer.

Elliptic.—Shaped like an ellipse (egg shape).

Fifth wheel.—A pivoted circular plate to support and steer the forward end of a vehicle.

Flexibility.—The ease with which an elastic body is deflected.

Frame.—The structural center of the chassis which serves as a foundation for a vehicle.

Frequency.—The number of vibrations, cycles, or changes in direction in a unit of time.

Friction.—The action between two bodies at the surfaces of contact which opposes their movement.

Gusset plate.—A plate at the joint of a frame structure of steel to strengthen the joint.

Integral.—The whole made up of parts; constituting a part of a whole necessary to completeness.

Laminated.—Made up of thin sheets, leaves, or plates.

Lever.—A rigid bar or beam of any shape capable of turning about one point called a fulcrum; used for transmitting or changing force or motion.

Leverage.—The mechanical advantage obtained by use of a lever; also an arrangement or combination of levers.

Linkage.—Any system of links or levers joined together to transmit motion or force.

Load rating.—Weight required to deflect a spring 1 inch.

Lunette.—An eye that hooks into a pintle hook to tow vehicles.

Mechanism.—A system of parts or appliances which act as a working agency to produce a desired effect.

Period.—Time required to complete one full vibration, as in a vehicle spring.

Pintle hook.—A swivel type hook used to engage with a lunette for towing trailers.

Radius.—Distance from the center of rotation.

Semi.—A prefix denoting half.

Shackle.—A swinging support which permits a leaf spring to vary in length as it is deflected.

Shim.—Spacer (usually metal) to regulate the distance between two objects.

Shimmy.—Abnormal sidewise vibration of the front wheels.

Shroud.—The forward subassembly of a body or cab containing the dash, cowl, and instrument panels.

Spring.—Flexible or elastic members that support the weight of a vehicle; an elastic body or device that recovers its original shape when released after being distorted.

Strain.—To cause a change of form or shape size by the application of external force; deformation or distortion due to stress or force.

Stress.—The forces exerted on, within, or by a body during either tension or compression; the opposing reaction of the interior elements of a solid body against forces tending to deform them.

Suspension.—A device by which something is suspended or hung; the system of springs, etc., supporting the upper part of a vehicle on its axles or wheels.

Tandem axles.—Two axles placed directly alongside of each other.

Taper.—To make gradually smaller toward one end; a gradual reduction of size in a given direction.

Thrust.—A stress or strain tending to push a member of a body or material out of alinement.

Toe-in.—The amount in inches that the front of the front wheels point inward.

Toe-out.—Difference in the turning radius of two steering wheels due to steering geometry; usually specified as the number of degrees over 20° through which the inner wheel is turned when the outer wheel is turned 20°.

Torque.—A twisting or wrenching effort. Torque is the product of force multiplied by the distance from the center of rotation at which it is exerted.

Torque rods.—Arms or rods used to insure accurate alinement of an axle with the frame and to relieve the springs of driving and braking stresses.

Tractor.—A motor vehicle specially designed for towing trailers.

Trailer.—A vehicle without motive power towed by a motor vehicle, designed to carry passengers or cargo.

Tramp.—The act of wheels treading or stamping heavily on the road at regular intervals.

Trunnion axle.—A supporting axle which carries a load with other axles attached to it. Its use as part of a "bogie" permits independent wheel action in a vertical plane and within designed limits.

Universal joint.—A device which transmits power through an angle.

Unsprung weight.—Weight of a vehicle that is not suspended by springs.

Wander.—To ramble or move without control from a fixed course, as the front wheels of a vehicle.

Wheel alinement.—The mechanics of keeping all the parts of the steering system in correct relation to each other.

Section II

FRAME

4. Requirements.—*a.* The frame (figs. 2 and 3) must be light yet strong enough to support the weight and rated load of a vehicle without being appreciably distorted, and it must be sufficiently rigid to protect units of the vehicle from stresses and strains.

b. A frame which is rigid enough to protect the body from considerable stresses (so that the doors may be easily operated at all times) is usually strong enough for a passenger vehicle. However, truck frame requirements are more severe since a considerable load besides the weight of the vehicle must be carried.

5. Construction.—*a.* The material most used for frame construction is cold rolled open-hearth steel, but sometimes heat treated alloy steel is used to obtain equivalent strength with less weight. The steel is usually cold pressed into shape to form strong, light frame members. Heavy duty trucks sometimes have frames made from **I**-beams or other structural forms.

b. The frame consists of two side members that run the length of the vehicle and cross members which unite these side members into a rigid boxlike construction. The side members of pressed-steel frames are invariably shaped like a channel, with the open side turned inward (figs. 2 and 3). Most of the cross members used are also of channel shape, although some frames have either one or more tubular cross members to increase resistance to twisting moments. The cross members are riveted or welded to the side members, and the joint is sometimes reinforced by gusset plates.

c. The side members are the most important parts and are formed from beams of considerable depth because they are subjected to large bending stresses. The depth of the side member of a passenger car frame is usually constant over the middle third and decreases toward

both ends. (See fig. 4.) This provides greater strength at the center of the frame where stresses are greater. Frequently the side members are "boxed;" that is, two channel sections are welded together into a rectangular section to provide additional strength.

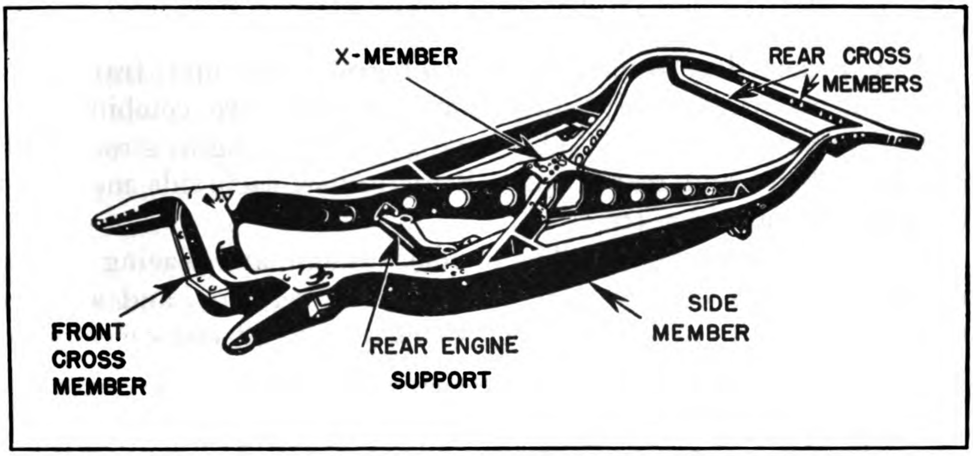

FIGURE 2.—Passenger car (X member) frame.

6. Plan.—*a.* The plan of the frame depends upon the type of vehicle and the general design of the chassis. Passenger car frames are generally narrowed at the front by tapering side members, which permit the front wheels to turn within a reasonably short radius. The part of the frame immediately under the body is generally made wider, since the body is much wider than the front of the frame and must be bolted either directly to the frame side members or to brackets riveted on the outside of them.

b. A frame with straight parallel side members is easier to manufacture and has more resistance to vertical bending movements resulting from the load. Since many military and commercial trucks are subjected to heavy loads, truck frames are usually made with straight parallel side members (fig. 3).

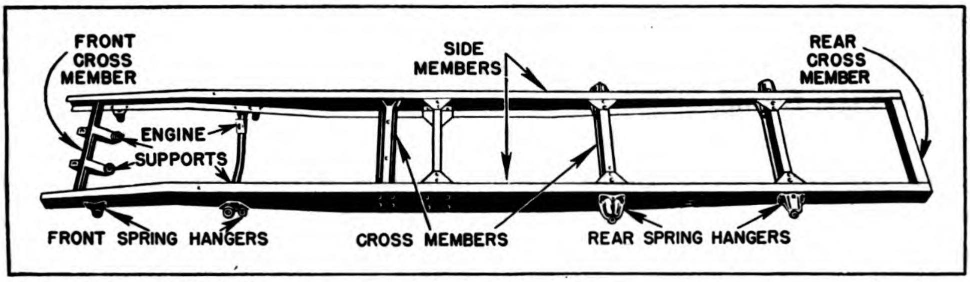

FIGURE 3.—Truck frame.

c. It is general practice to provide a "kick-up" at each end of the side members of passenger car frames (fig. 4) to lower the center of gravity of the vehicle and still allow room for the required vertical movement of the axle. "Kick-ups," which lower the strength of the frame, are satisfactory for passenger cars that are not subjected to heavy loads.

d. A recent development is the integral body and frame construction in which body and frame members are combined and welded into a single unit. This makes possible a light, strong, safe, and quiet body and frame unit. Structurally, each side member is designed like a bridge truss.

7. Cross members.—*a.* The number, design, and placing of cross members depend largely upon the general size, type, and arrangement of the units of the vehicle. Usually, a front cross member of

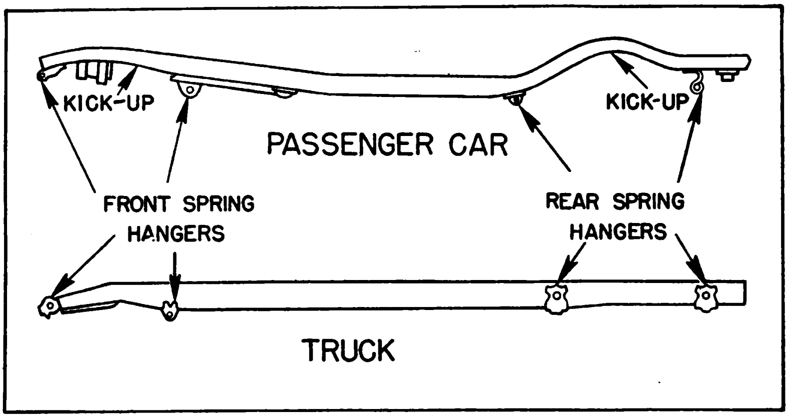

FIGURE 4.—Side view of typical frames.

channel or pan section supports the radiator and front end of the engine and stiffens the frame ahead of the body. The shape and placing of the front cross member depend upon whether the front support is through the conventional type of front axle or through some system of independent springing. A very wide and heavy front cross member is required with independent suspension (fig. 2). Usually a second cross member supports the rear of the engine and stiffens the frame.

b. Another cross member is generally found near the front support for the rear spring. This provides a firm support for the spring connection and stiffens the frame at this point. The frame must be firm here because the vehicle is driven or pushed through this connection, depending upon whether a Hotchkiss or torque tube drive is used. Rear cross members furnish supports for the fuel tank, rear trunk, etc.

c. Frames, especially those for passenger cars, often employ an X or K member in the center of the frame (fig. 2) to secure torsional rigidity or resistance to bending. The X or K member must allow room for the propeller shaft. Typical cross members for a truck frame are illustrated in figure 3.

d. Brackets attached to the frame support the shock absorbers, fenders, running boards, etc. Brackets are usually made of cast or pressed steel, although drop forgings are used where stronger brackets are needed. Brackets stamped from light steel stock are used when strength is not a major requirement. Hangers are provided on the side members for the springs. (See fig. 4.)

e. A frame may be distorted by "weaving" or "twisting." Weaving is the lengthwise displacement of one side member with relation to the other side member. It is caused by the forward end of one side member striking some obstruction. Twisting is distortion of the frame, such as occurs when one wheel receives a shock from an uneven road surface. The cross members resist weaving and twisting in addition to supporting certain of the vehicle units.

SECTION III

SPRINGS AND SHOCK ABSORBERS

8. Function of springs.—Springs act as a flexible connection between the wheels, which receive shocks from uneven road surfaces, and the frame and body, which carry the passengers or cargo. To do this the springs must support most of the weight of the vehicle. A portion of the vehicle weight, such as the wheels, rims, tires, brakes, and in some cases the axles, cannot be carried by the springs. This

unsprung weight should be kept at a minimum because it decreases the action of the springs. In the Hotchkiss drive arrangement, springs also transmit the driving thrust and absorb torque. In the torque tube and torque arm drives, the springs transmit no thrust or torque.

9. Factors of spring design.—*a. General.*—A comfortable or an uncomfortable ride in a spring-suspended vehicle depends on a number of factors. The most important factors in spring design that affect comfort are flexibility and frequency.

b. Flexibility.—(1) To establish their relative flexibility, springs are rated by the weight required to deflect them 1 inch. A soft or flexible spring requires comparatively little weight to deflect it 1 inch and therefore has a low load rating; while a stiff or inflexible spring requires much more weight to deflect it 1 inch and therefore has a high load rating.

(2) A soft or flexible spring will deflect more under a given load than a stiff or inflexible spring. It will therefore produce easier riding because it will give more readily when submitted to shocks.

c. Frequency.—(1) The rapidity of spring deflection, or the period of time required to complete one full vibration, depends on the frequency of vibration of the spring; that is, a spring with a high frequency of vibration will have a low period (completes one full vibration in a short time), and a spring with a low frequency of vibration will have a high period.

(2) The frequency of vibration, unlike the flexibility, is not a constant value for any one spring but varies with the load. As the load on a spring is increased, the frequency of vibration decreases. The frequency at which a spring vibrates also depends on its flexibility, since the higher the load rating of a spring the higher its frequency. High frequency springs give jerky or sudden vibrations, whereas low frequency springs give more comfortable riding because the vibrations are smooth or gradual. This is indicated by the difference in riding qualities between a lightly and a heavily loaded vehicle.

10. Spring requirements.—*a.* The important factor in designing a vehicle spring is the load which it must carry. Springs are designed to assume their proper shape under normal load, which for the semielliptic leaf spring is practically flat. The load rating of the spring to be used is definitely limited by the load, since a spring must not allow too great a vertical movement of the wheels. When the load rating, of necessity, must be high (to support heavy loads), the required stiffer spring will result in a hard-riding vehicle. A compromise must be made in designing a spring for a particular vehicle.

Springs having a low load rating are used on passenger cars in order to obtain comfortable riding. Springs having a high load rating are required on heavy duty vehicles to support the weight of loads, and riding qualities must be sacrificed.

b. The deflection of the front springs is purposely kept small because a large deflection makes the steering erratic. The rear springs of passenger cars are probably the most important factor in providing comfortable riding and they are therefore made as flexible as possible. Large rear springs with a high load rating are used on trucks because they must carry most of the load placed on the vehicle.

c. A spring should absorb the energy of the road jar or blow so that it will not be transmitted to the body of the vehicle or to the passengers. When a chassis spring is set vibrating, as by a shock from the road surface, it is deflected from its normal position and absorbs the energy from the shock. This energy is then stored in the spring and causes the spring to rebound and to pass through its normal position and deflect in the other direction. Internal friction within the spring will tend to dampen this deflection. The ideal spring would absorb the energy of the road shock through internal friction when it deflects and then return slowly to its normal position without rebounding. Such a spring, however, is not practicable.

d. Experience has proved that entirely satisfactory riding conditions cannot be obtained by using springs alone. A spring flexible enough for easy riding does not absorb enough of the energy of a severe road blow to prevent an excessive rebound. To remedy this situation, spring control devices, called shock absorbers, are employed in connection with the springs. (See par. 19.)

11. Leaf spring.—*a*. The type of spring most extensively used on motor vehicles is the laminated leaf spring. It is built up of a number of steel strips or leaves of different lengths placed one on another (fig. 5). Each end of the longest or master leaf is usually rolled into an eye to serve as a means of attaching the spring to the frame. The

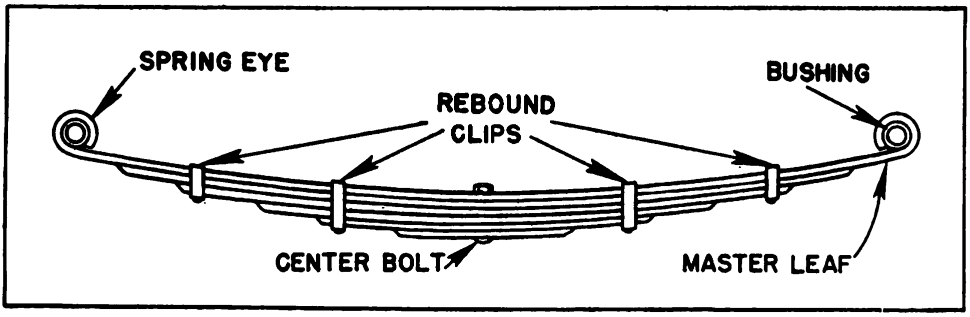

FIGURE 5.—Laminated leaf spring.

lengths of the other leaves usually decrease uniformly with their distance from the master leaf. One of the reasons for using multiple leaves of various lengths is to make the strain substantially uniform in all parts of the spring. Truck springs are sometimes provided with elongated eyes, or box eyes, which slide on rollers on the spring mountings. They are also made without eyes at either one or both ends; the ends then slide on bearing plates and guides.

b. The leaves are usually fastened together by a bolt through their centers. One objection to the center bolt is that the hole through the spring material weakens the spring, often causing breakage at this point. For this reason, the leaves are sometimes fastened together by bands or clamps. Nibs or grooves are then shaped on the leaves to prevent their shifting.

c. The leaves are made from rolled stock, and after cutting to length, each leaf is bent or "nipped" to form an arc with a definite radius, which decreases with the shorter leaves. It is necessary to press the leaves together to assemble the spring. This puts the leaves under a small initial stress and helps to prevent dirt and water from getting between the leaves.

d. "Nipping" decreases the stress in the master leaf and increases the stresses in the shorter leaves. Within certain limits this is desirable because it tends to make the shortest leaf the "weakest link" and it is certainly less objectionable to have a short leaf break than the master leaf. However, a large difference in the stresses on the different leaves is undesirable because then some of the spring material is not utilized to full advantage. To prevent large differences, the springs are sometimes "graded," that is, the shorter leaves are made of thinner stock so that a given deflection under load does not increase the stress on them as much as it increases the stress on the master leaf.

e. When a laminated leaf spring is depressed by a load, the stress is resisted by all the leaves. However, when the rebound occurs after the spring is depressed or when the wheel suddenly drops in a hole in the road, the direction of the stress is reversed. This may separate the leaves, throwing most of the stress on the master leaf. To transfer some of the stress to other leaves, rebound clips (fig. 5) are provided. These are in the form of straps which surround all the leaves at two or more points along the spring. The clips must allow the leaves to slide but prevent them from separating on the rebound.

f. A common type of rebound clip consists of a U-shaped steel strap riveted to the shortest leaf of those it surrounds. The ends are sometimes bent around the master leaf; or are separated by a

hollow spacer and bolted together over the master leaf. Another type is inverted—the bolt passing through a small eye rolled in the tip of the shortest leaf. To decrease the rebound further, two and occasionally three of the leaves may be made full length and may even wrap around the spring eyes.

12. Leaf spring theory.—*a.* The load rating of a laminated leaf spring is governed by the number, thickness, and length of the leaves. For any definite length, greater deflection and flexibility are obtained with thin leaves, which demands the use of high grade material, such as alloy steel. Thick leaves of plain carbon steel are used for stiffer springs.

b. Two forces are at work on a deflected leaf: the force due to the load carried, and the force due to the internal strains of the spring material. The load force is constant for any one load, but the internal strain force increases with the deflection and reaches a maximum at the maximum deflection point. When a multiple leaf spring is deflected, one leaf slides over another, which introduces friction. This friction between the leaves opposes the deflection and therefore assists the internal forces or those due to strains in the material. While the spring is deflecting, the difference between the force due to the load on the spring and that due to the internal strain overcomes the frictional resistance. When this difference becomes equal to the frictional resistance the deflection ceases. The greater the number of leaves the less the spring deflection, because of this friction between leaves. To obtain very flexible springs, the interleaf friction should be brought down to a minimum. This may be done by using only a few leaves or by grooving the leaves lengthwise to cut down the area of contact.

13. Leaf spring mountings.—*a.* Many types of leaf spring mountings have been used on motor vehicles. All of the older types have been made of a combination of semielliptic springs or partly semielliptic and partly of quarter-elliptic members; such as the full elliptic, the three-quarter elliptic, the platform, and the cantilever spring mountings. All these, however, have almost entirely passed out of use.

b. When suspension is obtained by laminated leaf springs, the present practice is to use single semielliptic springs (fig. 5). A loaded laminated leaf spring has a maximum deflection from a shock when the spring is straight. Since deflection is what produces the essential springing action, the tendency is to design springs so that they are absolutely straight when under their total rated load. The distance from a line joining the centers of the spring eyes to the center of the

outside of the master leaf is known as the spring camber or the opening of the spring. Hence, a semielliptic spring should usually have zero camber when normally loaded, a moderate positive camber when unloaded, and a negative camber when under its rated shock load.

c. In nearly all cases, semielliptic springs are mounted lengthwise on the vehicle. The ends are usually attached to the frame spring hangers by bolts or pins through the spring eyes and are clamped to the axle on a spring seat. In passenger cars the length of the front springs is about 35 percent and the rear springs about 50 percent of the wheelbase of the vehicle. In the Hotchkiss drive, the spring is held rigidly to the axle housing. In the torque tube and the torque arm drive, the spring is held by flexible connection to the axle housing to prevent it from transmitting torque. Rear springs of trucks frequently pass under the axle instead of over it, thereby lowering the center of gravity of the vehicle.

d. In the transverse mounting, which is used by a few manufacturers, the springs are mounted crosswise of the vehicle. The two ends of the spring are attached to the axle, and the vehicle frame rests on the center of the spring. The length of transverse springs is limited by the available distance between the wheels. Torque arms must be used with this mounting since the springs cannot transmit any driving thrust or absorb any torque. Springs of higher load ratings are necessary because each spring must support about half the vehicle weight compared to about one-quarter of the vehicle weight that must be supported by each spring in the lengthwise mounting. Hence, the riding qualities obtained from transverse mounting are usually not as good as those obtained by lengthwise mounting.

14. Spring bushings.—*a.* (1) Spring eyes are generally bushed with a bronze bearing, though rubber bushings are sometimes used. Bushings may be press fitted or screwed into the eyes depending on the design. The object of the bushing is to permit renewing a wearing surface at low cost. Spring bolts or pins, which may be either threaded or smooth, pass through these bushings for attaching the spring to the hangers provided on the frame. (See figs. 6 to 10, inclusive.)

(2) The bushing and the spring bolt or pin, therefore, form the bearing surfaces which support the load on the spring. Much more bearing surface is available with threaded than smooth surfaces.

b. Because there is considerable movement between bearing surfaces when the spring vibrates, it is necessary to provide means for lubrication. Usually the bolt or pin is drilled through the center for half of its length, with a side hole at its middle so that a lubricant

can be forced through a lubricant fitting, onto the bearing surfaces. Sometimes a groove is made in the center of the bolt or pin to hold lubricant there. (See figs. 7 to 10, inclusive.) Cork or synthetic rubber washers are often fitted between the bushings and hangers to prevent loss of the lubricant. Spring bolts are subjected to hard service and considerable wear takes place if proper lubrication is not provided.

c. Rubber bushings are usually made from molded rubber enclosed within an inner and outer steel shell (fig. 6). The outer shell is

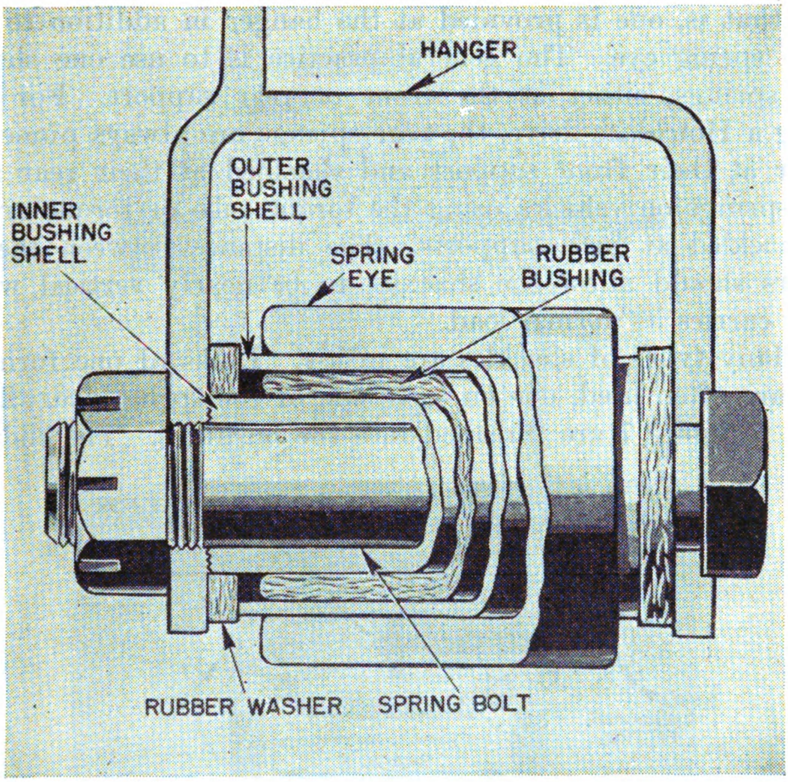

FIGURE 6.—Spring hanger with rubber bushing.

press fit into the spring eye and the inner shell rigidly held in the hanger by tightening the spring bolt, serrations (saw teeth) being provided on the ends of the inner shell to bite into the hanger. In this manner, all movement between the spring and bolt is taken up by the rubber so that no lubrication is required. Rubber washers are inserted between the ends of the outer bushing shell and the hanger to prevent all metal-to-metal contact between the spring and the hanger.

d. A spring bolt or pin must be tightly secured against rotation in the spring hanger so that all relative motion will be between it

and the bushing. One method of doing this is to use a bolt knurled under the head so that it bites and does not turn when pressed intc the metal of the hanger. In another method a seat is provided in the hanger for the bolt head so that it cannot turn. A pin can be secured against rotation by a key or a clamp bolt that fits into a groove provided in the pin.

15. Spring shackles.—*a.* The spring shackle, a swinging support which permits the leaf spring to vary in length as it is compressed, is mounted between the spring and the hanger by bolts or pins. Since movement occurs at both ends of the shackle, two bushings are used; that is, one is provided at the hanger in addition to the one in the spring eye. The general practice is to use one shackle on front springs, either at the front or rear support. For vehicles having a Hotchkiss drive, the rear springs are always pinned to the hanger at their front support and shackled at their rear support. Rear springs on vehicles using the torque tube or torque arm drive are shackled at both supports. The distance between the spring hangers should allow the shackles to be nearly vertical when the spring carries its normal load.

b. Many types of shackles are in use. Links of one form or another are often used, one on each side of the spring eye. The pins shown in figure 7 are threaded into the bushings. The ends of the

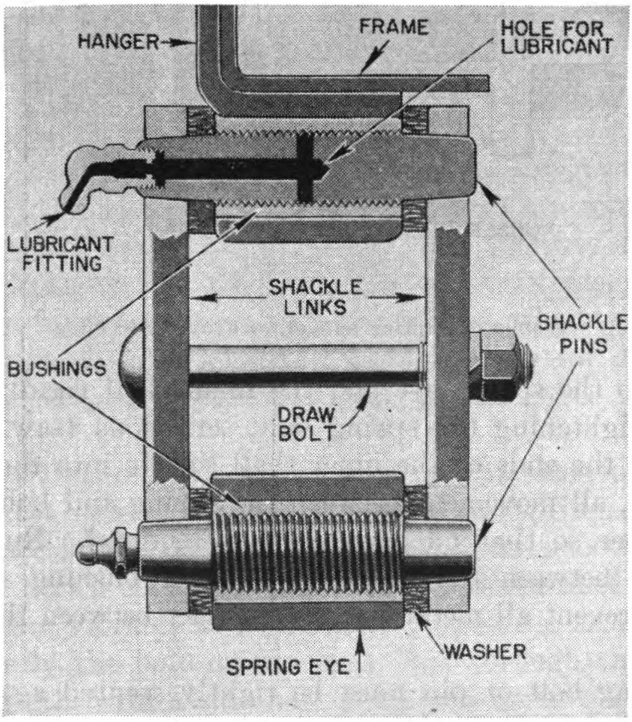

FIGURE 7.—Link shackle.

pins are tapered to fit snugly into the shackle links, which are held together by a draw bolt to lock the pins in position. Individual links, without any connection between them, can be used with shackle bolts locked in the links.

c. Shackle links may be combined into a single unit construction by means of a center cross bar or by making it a single piece (fig. 8). The shackle bolts are locked in the link (by knurled bolts in fig. 8). For this type of shackle, some play must be allowed between the shackle link and the spring eye and hanger so that free movement can occur between them. When assembling, the shackle bolts are

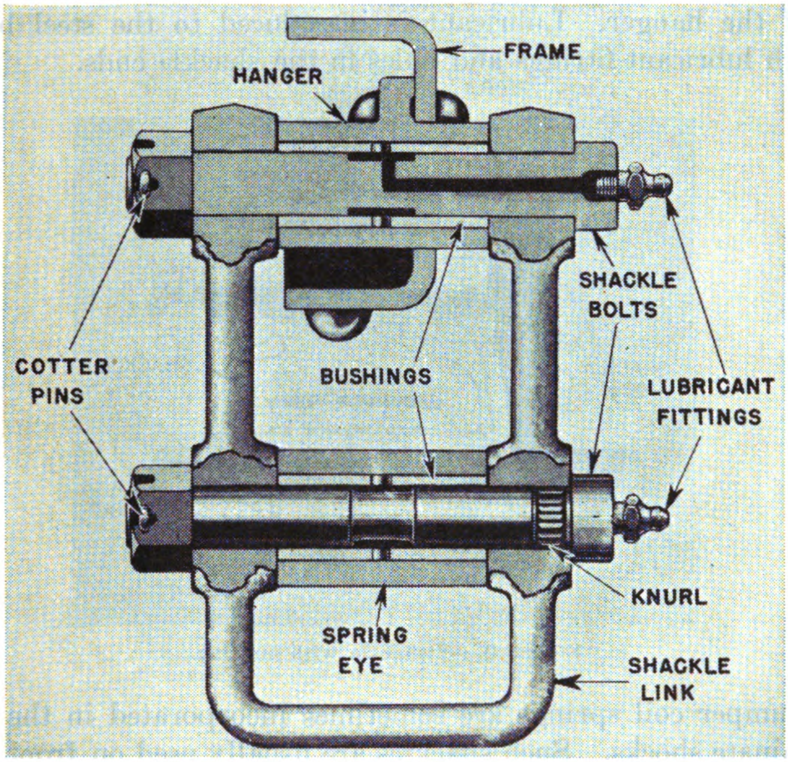

FIGURE 8.—Single piece link shackle.

drawn up as tightly as possible, then backed off about one-half turn to prevent binding. The nuts are held on the shackle bolts by cotter pins.

d. Another type of shackle, in which one of the bushings is fitted into the shackle, is illustrated in figure 9. The plain shackle pins are locked in position by small clamp bolts. This solid Y-shaped shackle can be made very rigid and is a good design for heavy duty vehicles.

e. The U-shackle, in which the shackle bolts and shackle are combined into a single unit by a U-shaped forging with threaded ends

(fig. 10), is used in spring mountings on a large number of passenger cars. Upper and lower threaded bushings are used to hold the U-shackle ends. These hardened steel bushings are tightly threaded into the frame hanger and into the spring eye, and loosely threaded over each end of the U-shackle. Free movement is then allowed between the steel bushings and the shackle ends. The outer threads on the bushing are very coarse, while those which screw over the bolt are finer. The outer threads are threaded in the opposite direction to the inner threads so that the shackle end is drawn into the bushing as the bushing is turned into the hanger or spring eye. These shackles may be inserted either through the inner or outer end of the hanger. Lubricant is introduced to the steel bushings through lubricant fittings and holes in the shackle ends.

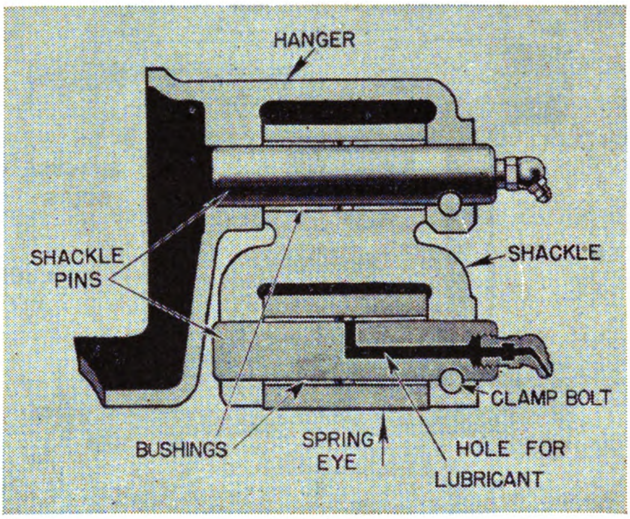

FIGURE 9.—Y-shackle with bushing.

f. Bumper coil springs are sometimes incorporated in the shackle to eliminate shocks. Such shackles are usually used on front springs and are called kick shackles. They help to reduce the transmission of road shocks to the frame and to the steering wheel thereby helping to avoid front wheel shimmy.

g. Blocks of rubber, confined in boxlike housings on the frame, can be used instead of bolts and shackles on the springs. The ends of the main leaf are then flat and fit between the blocks of rubber. This installation does not require lubrication since there are no metal bearing surfaces.

16. Leaf spring lubrication.—*a*. Some manufacturers and designers of springs do not advocate spring-leaf lubrication because reducing friction between the leaves destroys the capacity of the

spring to absorb the energy of shocks without excessive rebound. However, it is generally necessary to keep the leaf surfaces lubricated to prevent undue wear and squeaks and to keep a spring flexible. The leaf surfaces should be lubricated by spraying them with oil or by forcing grease, usually a graphite grease, between the leaves. Many vehicles have spring covers to retain the lubricant, and some have fittings to replenish the lubricant. These covers keep the spring surfaces lubricated and also protect the spring from water, dirt, snow, and other foreign matter. Spring leaves should be sprayed with oil or lubricated with grease seasonally (twice a year).

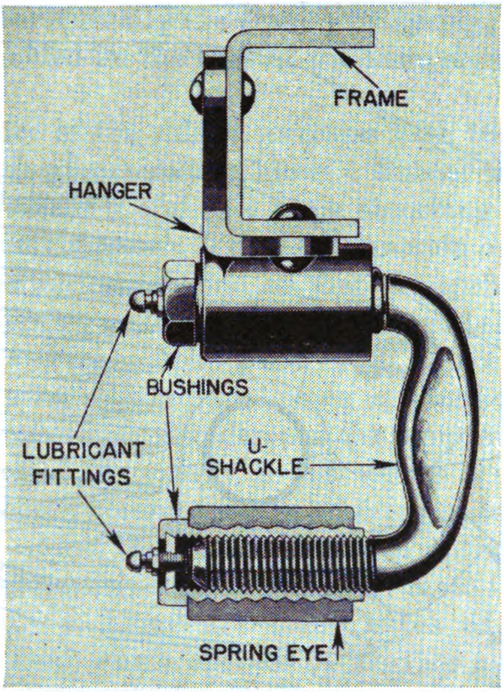

FIGURE 10.—U-shackle.

b. Some leaf springs have thin rubber inserts placed between the leaves so that there is no metal-to-metal contact. No lubrication is then needed between the leaves as the rubber gives when there is a tendency for one leaf to slide on another. Other leaf springs have self-lubricating bronze inserts.

c. Spring bolts and shackle bolts, when not rubber mounted, and the spring seat on torque tube drives are usually fitted with pressure grease fittings. These should be lubricated every 1,000 miles with semifluid chassis lubricant.

17. Coil springs.—*a.* Coil springs (fig. 11) are coming into wide use for passenger cars, particularly with independent wheel suspen-

sion. They are made of alloy steel rods coiled to the desired size. The load rating of a coil spring depends on the diameter and length of the rod used to make the spring. Greater flexibility is obtained by using a long rod with a small diameter. The effective length of coil springs can be made much longer than leaf springs since the active spring material is coiled into a small space. Therefore, it is easier to obtain the desirable spring flexibility and frequency for a particular vehicle.

b. Since the coil spring is all one piece there is no friction as there is between the leaves of a leaf spring. Since there is no friction to

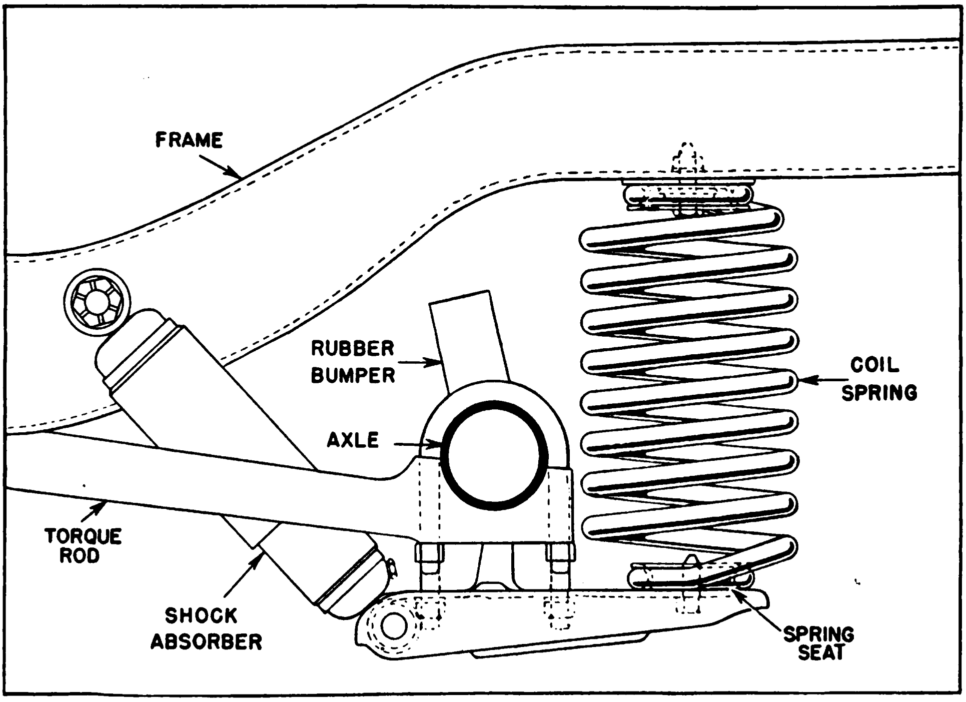

FIGURE 11.—Coil spring mounting.

oppose deflection of the coil spring, the deflection of the spring absorbs the energy of a road shock by the resistance of the internal strain force of the spring material only. Because coil springs are so flexible, good shock absorbers must be used with them to prevent excessive rebound.

c. The coil spring can be used for springing only and cannot transmit any side thrust nor take any torque reaction. Therefore, it must be used with suitable torque rod structure (fig. 11), which will take these thrusts and hold the axle in alinement.

d. Coil spring mountings are very simple. The hanger and spring seat are shaped to fit the coil ends and hold the spring in place (fig. 11).

Cups which fit snugly on each coil end are often used for mounting a coil spring (fig. 21). With independent suspension, the upper cup is usually formed within the frame and the lower cup fastened to independent arm supports. Rubberized fabric spacers are placed into the cup to insulate the springs.

18. Rubber bumpers.—*a*. Rubber bumpers are mounted either on the spring or its supporting member to prevent metal-to-metal contact when the spring is compressed. With independent suspension, the suspension arms sometimes butt against rubber bumpers. Rubber bumpers are usually block or cone shaped (figs. 11 and 21). They are mounted by bonding them to a metal strip that is fastened to the supporting member (usually the frame) or spring; or by means of a rubber button, molded on the base of the bumper, that fastens into a hole in the frame.

b. The resistance of the rubber increases with the deflection of the spring and helps to absorb sudden blows. Rubber has many desirable properties that make it useful as a shock absorbing medium.

19. Shock absorbers.—*a*. The main function of a shock absorber is to regulate the spring rebound so that the spring returns to rest slowly, thus preventing sudden jolts and bounces being transmitted to the vehicle body and its occupants and cargo. Shock absorbers which only check the spring rebound are known as single acting.

b. A shock absorber may also dampen the compression of the spring by absorbing part of the energy as the spring is depressed. Shock absorbers which check compression in addition to rebound are known as double acting. Most shock absorbers used at the present time are double acting because they permit the use of more flexible springs.

20. Operation.—*a*. There are many types of shock absorbers. Some have been used which operate by friction and spring tension. Those used at present are hydraulically operated and depend upon the resistance of a liquid flowing through a restricted opening to dissipate the energy of the spring.

b. The principle of the hydraulic shock absorber is rather simple. Oil contained within a housing is forced through a restricted opening by a piston when the vehicle spring flexes. Since liquids are not compressible, the oil takes a certain time to flow through the restricted opening. The rate of piston travel, which controls the period of spring vibration, is determined by the opening through which the oil must flow. The energy of the road shocks imposed on the spring is dissipated by a shock absorber in forcing the oil through the opening.

c. The shock absorber is attached to the frame of the vehicle (fig. 18). Most shock absorbers contain a lever pivoted to a shaft in the housing.

This lever is pinned to a link, the other end of which is usually attached to the spring seat or spring clip. Rubber grommets are used at either end of the link to prevent metal-to-metal contact. With independent suspension, the shock absorber lever is often used as the upper control arm of the spring mounting (fig. 20).

d. In the more common types of shock absorbers the lever, which is moved by spring action, operates a cam that actuates the piston. In some types the lever operates a vane which acts as a piston. On one type of shock absorber widely used on passenger cars the piston is directly operated by spring action.

21. Cam shock absorbers.—*a. Single acting.*—(1) A cam operated shock absorber designed to check the rebound only is shown in figure 12. The housing or body contains an oil-filled reservoir

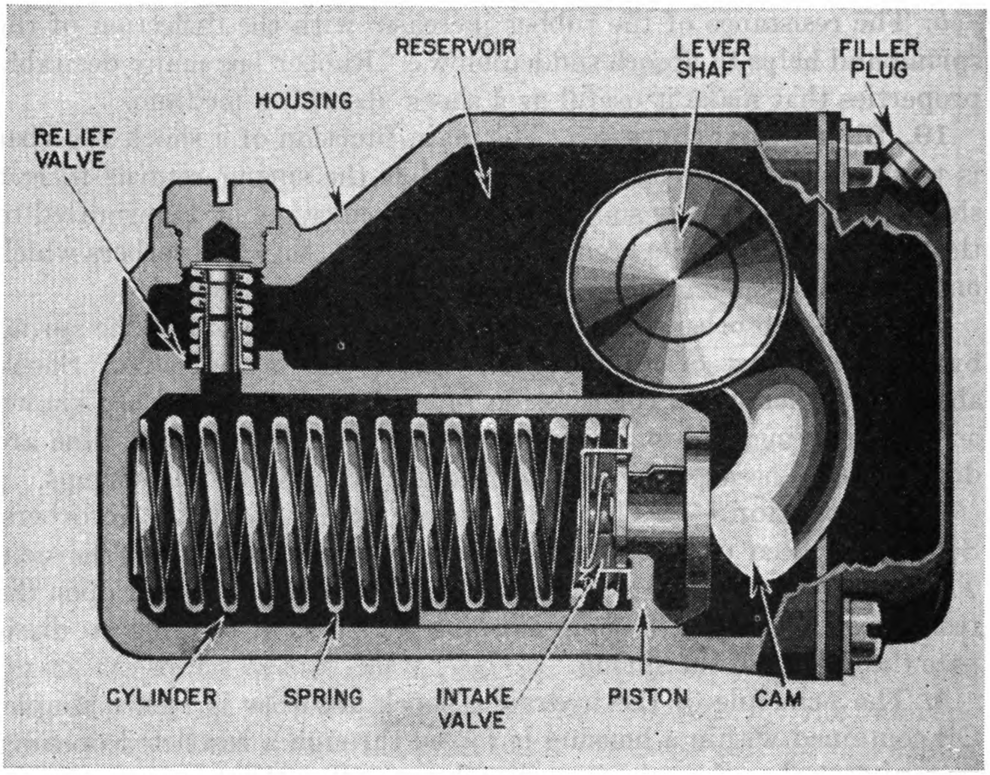

FIGURE 12.—Single acting shock absorber (cam operated piston).

and an inner cylinder. Within the cylinder is a piston operated by a cam mounted on the shaft to which the lever is mounted. The piston is held against the cam by a coil spring in the cylinder. Inside the piston is an intake or check valve which permits oil to enter the cylinder from the outer reservoir. The cam moves to the right when the vehicle spring is compressed. The piston spring forces the

piston to follow the cam, opening the intake valve and allowing oil to flow into the cylinder. This valve has a large port opening so that it offers little resistance to the flow of oil and has, therefore, little effect upon the action of the vehicle spring.

(2) When the vehicle spring rebounds, the cam is moved in the reverse direction and forces the piston to the left against the oil in the cylinder, closing the intake valve. The motion of the piston forces the oil confined in the cylinder through the relief valve to the outer reservoir. The escape of oil through this valve is controlled and regulated by the size of the opening and by the valve spring pressure holding the valve against its seat. The instant the vehicle spring stops its rebound the relief valve is closed by its valve spring. The valves shown in figure 12 may have an entirely different construction and arrangement than the type shown. The relief valve is sometimes included in the piston along with the inlet valve.

b. Double acting.—(1) The operating principle of the double acting shock absorber is the same as the single acting shock absorber except that it provides a dampening action in both directions. One type of double acting shock absorber operated by a cam is shown in figure 13. The housing contains an oil reservoir and two cylinders. The

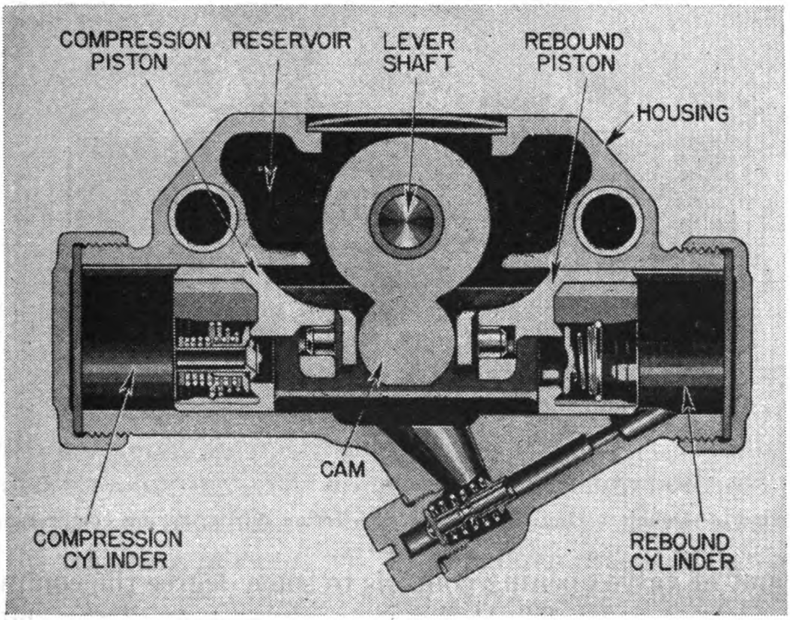

FIGURE 13.—Double acting shock absorber (cam operated piston).

cam is inserted between two interconnected pistons, each contained within a cylinder. The double acting pistons may operate in opposed cylinders made from one bore (fig. 13) or in side by side cylinders with a double arm cam (fig. 23).

(2) As the cam moves, due to the action of the vehicle spring, it carries both pistons with it (figs. 14 and 15). Each piston has a valve inside to check the flow of oil from the reservoir to either chamber as the pistons move. The shock absorber illustrated has the intake and relief valves for the compression cylinder contained within the compression piston; but only the intake valve for the rebound cylinder is in the rebound piston. The rebound relief valve is in a separate passage leading from the end of the rebound cylinder to the central reservoir. This permits better control of the flow of oil through the relief valve. A separate passage can also be provided for the compression relief valve. Both the intake and the relief valves are contained in each piston in the shock absorber illustrated in figure 23. The combination of valves used does not affect the operation, although better control may be obtained by separate valves.

(3) When the vehicle spring is compressed, the cam forces the compression piston to the left into the compression cylinder. The pressure exerted on the oil in the compression cylinder opens the compression relief valve (fig. 14) and oil slowly passes through it to the reservoir.

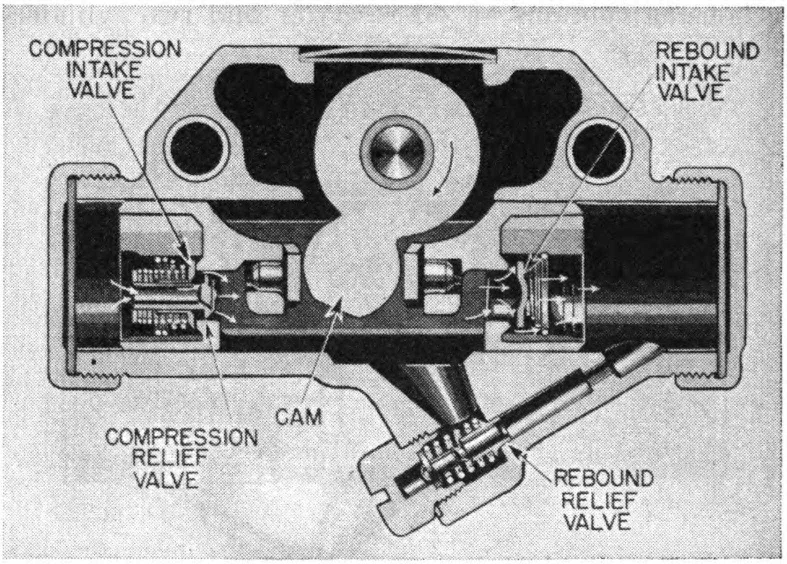

FIGURE 14.—Double acting shock absorber—action during spring compression.

The amount of valve opening controls to some degree the compression of the vehicle spring. While the compression side of the shock absorber is operating, the rebound piston is carried with the cam and the rebound intake valve opens to admit oil from the reservoir into the rebound cylinder.

(4) As the vehicle springs rebound, the cam carries both pistons to the right (fig. 15). The oil in the rebound cylinder flows down the passage through the rebound relief valve to the reservoir. The rebound of the vehicle spring is controlled by the size of the valve opening that the oil must flow through. Oil is supplied at the same time from the reservoir to the compression cylinder through the compression intake valve.

(5) Some shock absorbers contain a device to vary the dampening effect of the vehicle springs. The speed of compression or rebound can be varied by providing an additional relief valve whose opening can be controlled either manually or by an inertia weight. A manually controlled valve can be operated from the instrument panel

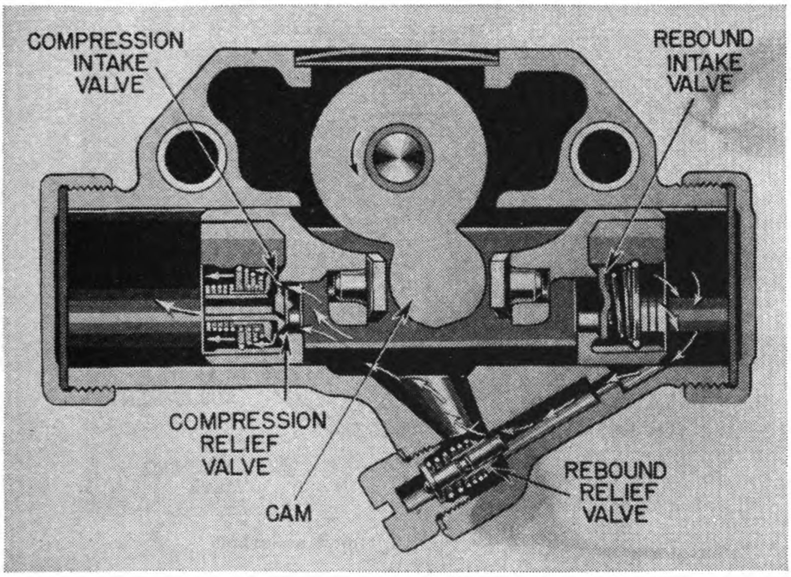

FIGURE 15.—Double acting shock absorber—action during spring rebound.

through a linkage. A valve controlled by an inertia weight will automatically control the rebound of the vehicle spring. On smooth roads the additional relief valve is held open by the inertia weight which is suspended by a spring. The oil then flows through both relief valves when the spring rebounds. When the vehicle spring receives a severe shock, the resulting rebound will be so sudden that the inertia weight will lag, closing the additional relief valve momentarily. All the oil will be forced through the main rebound relief valve in the piston, and the dampening of the spring action will be increased automatically.

22. Vane shock absorber.—*a.* In a vane type shock absorber (fig. 16) the oil is forced through restricted openings by vanes which

act as pistons. A cylindrical housing filled with oil is divided into two working chambers by stationary partitions. A vane contained on a central shaft which is operated by the shock absorber lever extends into each working chamber. The vanes therefore oscillate with the vehicle spring and act as pistons.

b. There is a check valve in each partition which permits the liquid to flow through the partitions when the vanes are moved by the compression of the vehicle spring. On the rebound stroke, the vanes move in the opposite direction and exert pressure on the oil, forcing the check valves to close so that the oil has to return to the other side of both partitions through a needle relief valve in the center of the shaft. A manual adjustment is usually provided to change the position of the needle which controls the size of the

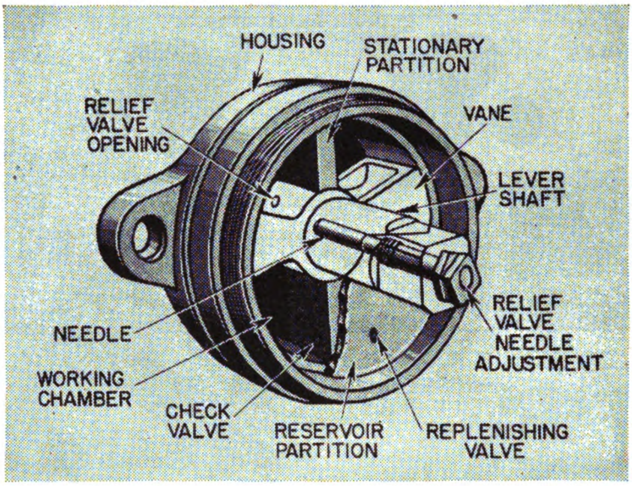

FIGURE 16.—Vane shock absorber.

relief valve opening and thereby regulates the resistance on the rebound strokes. In another type of vane shock absorber the relief valve is contained in the stationary partition. A bypass cut in the wall of the housing at the normal position of the vane (corresponding to the stationary position of vehicle spring) allows the fluid to pass by the vanes and offers little resistance to spring action on gentle bumps.

c. To get maximum performance, the working chambers must be completely filled with liquid and free from dirt so that the valves can open and close freely. Replenishing valves at the bottom of the housing allows oil to flow to the working chambers from a reservoir separated from the working chambers by a partition. These valves close when the liquid in the working chamber is under compression.

23. Direct acting shock absorber.—*a.* The direct acting shock absorber (fig. 17) consists of an inner cylinder, filled with a special shock absorber oil, divided into an upper and lower chamber by a double acting piston. The shock absorber is mounted by stud and rubber bushings inserted through the eye on each end so that it is directly acted upon by spring action (figs. 11 and 21). The piston push rod is therefore forced up and down within the inner cylinder.

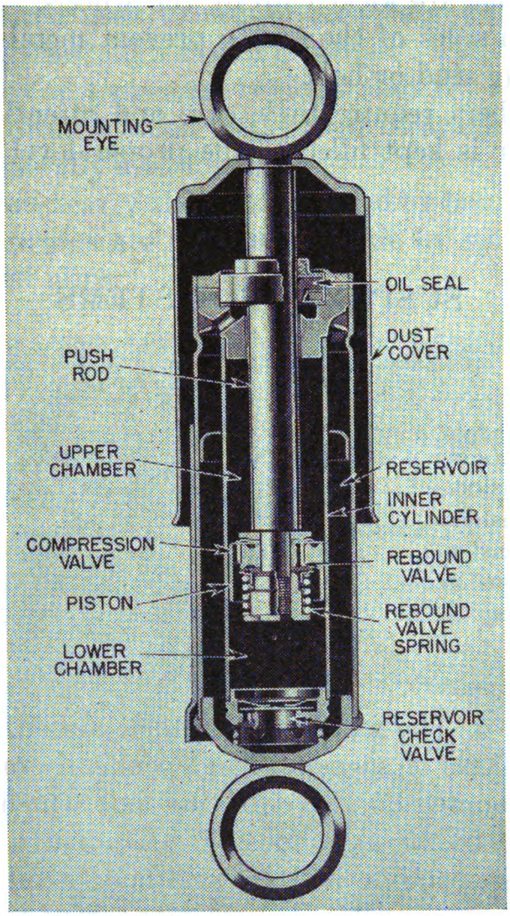

FIGURE 17.—Direct acting shock absorber.

A reservoir which contains ample supply of oil surrounds the inner cylinder and is joined to it by a reservoir check valve.

b. When the vehicle spring is compressed, the piston is forced down, and some of the oil below the piston is forced through compression valves (only one is illustrated) inside the piston into the upper chamber. These valves operate only on the down stroke. Since the push rod moves into the cylinder on the down stroke, some of the oil in the lower chamber is forced through the reservoir check valve at the bottom of the cylinder into the reservoir.

c. When the vehicle spring rebounds, the piston is moved up, and oil from the upper chamber is forced into the lower chamber through spring loaded rebound valves inside the piston. These valves control the rebound of the vehicle spring. As the piston moves out of the cylinder, oil is drawn into the lower chamber from the reservoir through the reservoir check valve.

d. An outer metal cover protects the shock absorber from damage by stones, etc., that are kicked up by the wheels. Rubber bushings are fitted on both sides of the eye to prevent metal-to-metal contact with the mounting stud or bolt.

e. Shock absorbers require little care and attention except to see that the reservoir is kept filled to the proper level with the proper fluid.

SECTION IV

SUSPENSION SYSTEMS

24. General.—*a.* The wheels of a vehicle are either mounted on a spring-suspended axle or suspended independently on springs. Driving wheels are mounted on a live driving axle which is suspended by a spring attached to the axle housing. Laminated leaf springs are usually used for suspending live axles, although coil springs are used on a few passenger cars with torque arm or torque tube drive.

b. The front wheels of rear drive motor vehicles were nearly always mounted on a dead axle until recently. Dead front axles are still used on a few passenger cars, however, and are extensively used on trucks and other heavy vehicles. The development of satisfactory independent suspension systems did away with front axles on most passenger cars. A live front axle, which acts as a driving member, is used in front or 4-wheel drive designs. The construction and suspension of the front axle are then similar to the conventional rear axle except for the provision for steering. Live axles are discussed in TM 10–585.

25. Dead axles.—*a.* Dead axles must be able to support the weight of the vehicle and also be able to resist the stresses that occur when the brakes are applied. They must have sufficient stability to keep the wheels in proper alinement so that the vehicle holds its course.

b. Dead axles are generally made of I-section, drop forged from medium carbon or alloy steel, and heat treated to give them toughness and strength. The more expensive tubular section made from molybdenum steel is often used to reduce unsprung weight and give the axle resistance against high braking torque. The center of the axle is usually dropped in passenger vehicles (fig. 18) so that the vehicle weight can be lowered when little road clearance is required. A straight axle is generally used for trucks.

c. Dead axles are nearly always suspended by laminated leaf springs (fig. 18). The springs are held on the axle by spring seats and are attached by U-bolt clips.

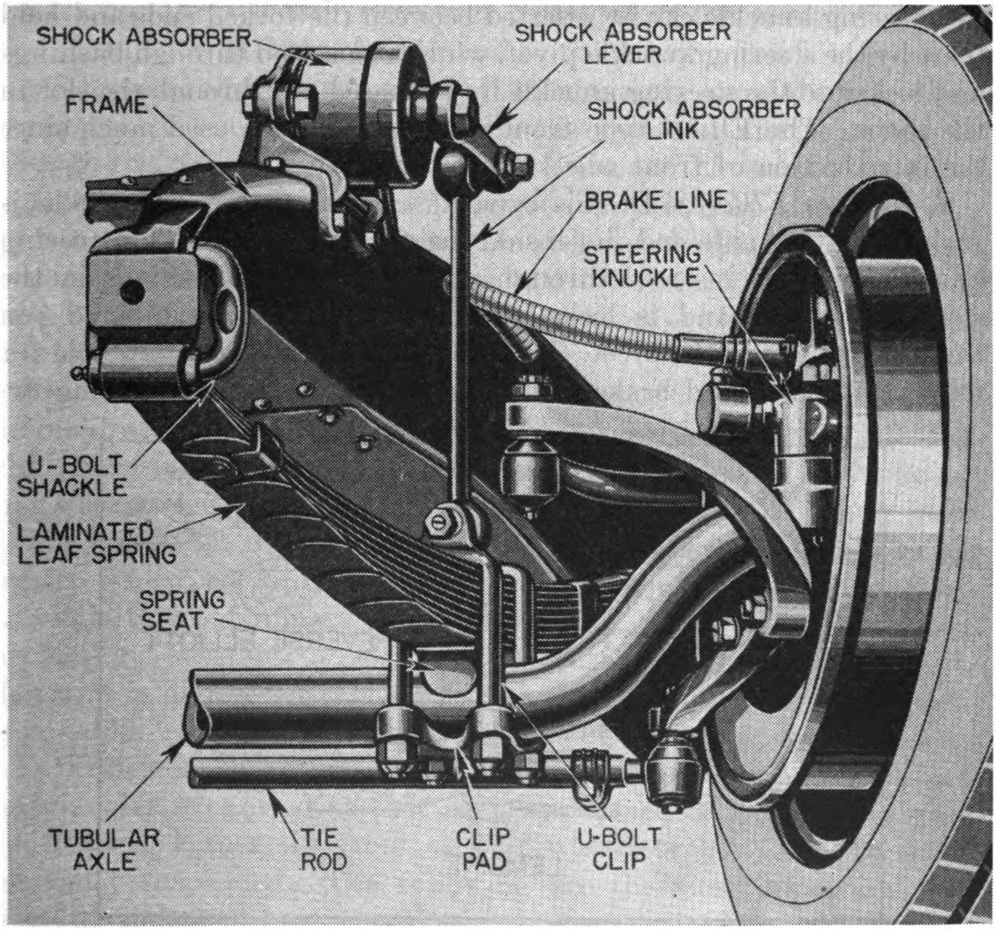

FIGURE 18.—Front (dead) axle suspension.

26. Front axles.—*a. General.*—The front axle of a conventional motor vehicle is a dead axle. To permit steering the front wheels of a motor vehicle, the front axle is made in three sections joined together. Each wheel is mounted on a spindle contained on the outer swinging section—the steering knuckle; while the middle section of the axle—the axle proper or axle bed—is held in position by springs or torque rods.

b. Designs.—Various axle designs are used for joining the steering knuckles to the ends of the axle proper. Pivot pins, called steering knuckle pivots and commonly known as king pins, hold the knuckles to the axle proper and permit the necessary movement of the knuckles for steering. The steering knuckles should be free to turn about their pivots about 40° either way from the center line of the axle. The steering knuckle pivot is slotted so that it can be held in position by a tapered pin.

c. Elliott.—The ends of the Elliott axle (fig. 19) are forked so that the steering knuckle can be inserted between the forked ends and held there by the steering knuckle pivot, which is inserted through bushings and locked to the steering knuckle by a tapered pin through the slot in the pivot. The Elliott type front axle has not been used much since the introduction of front wheel brakes.

d. Reverse Elliott.—In this type of axle, the steering knuckle is forked and the axle end fits inside the fork (fig. 19). The steering knuckle pivot is inserted through upper and lower bushings in the steering knuckle and is locked in the axle end by a tapered pin through the slot in the pivot. This design is much more adaptable for use with front wheel brakes. It also permits a simpler steering ar-

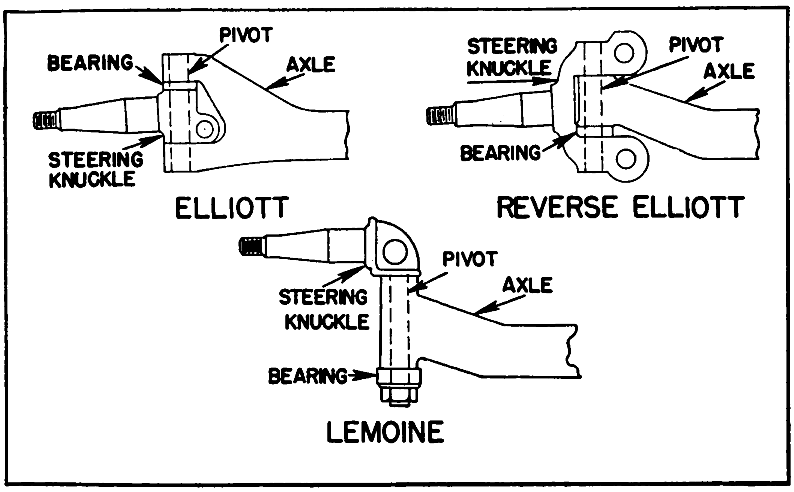

FIGURE 19.—Front axle designs.

rangement, since the axle end is not as large as it is with the Elliott forked axle end and allows more room for the steering linkage.

e. Lemoine.—A third front axle design, used in a few rare cases, employs an L-shaped steering knuckle joined to the axle end. Neither the steering knuckle nor the axle end is forked. The L-shaped knuckle is sometimes carried below the axle end, just the reverse of that shown for the Lemoine design in figure 19.

27. Steering knuckles.—*a.* Steering knuckles are generally made of alloy steel. They must necessarily be made of high grade materials because their failure would be a very serious matter and because their complicated form tends to localize stresses.

b. The load of the vehicle is placed upon the axle proper or axle bed by the springs. This load is carried through the steering knuckle pivot to the wheel spindle on the steering knuckle where it is supported by the wheel. Ease in steering depends on the easy movement of the steering knuckles. Since they carry the weight of a vehicle, antifriction thrust bearings must be provided at the point where the load is transferred from the axle end to the steering knuckle.

c. Tapered roller bearings or ball bearings are usually used. The upper race carries the weight from the axle end and transfers it through the rollers or balls to the lower race on the steering knuckle. A tapered roller bearing can take side thrusts and therefore can replace the lower bronze bushing for guiding the pivot through the steering knuckle. In some designs two tapered roller bearings are used to carry the axle load as well as to provide guides for the knuckle pivots.

28. Independent suspension.—*a.* If one of the two wheels mounted at opposite ends of a rigid axle receives a jar or jolt, the whole suspension system, including the axle, is affected. This means that a large unsprung weight is set in motion, which results in poor riding qualities. When a wheel hits an obstruction, the force of impact is directly proportional to the unsprung weight carried by it. This force of impact strains the wheels, axles, springs, steering mechanism, etc., and it also has a destructive effect on the road. Hence, it is highly desirable to reduce the unsprung weight as much as possible.

b. With independent suspension, the wheels of a motor vehicle are individually supported so that each will function independently of the others. Either the front or rear wheels or both may be independently suspended. The following are the most important features of independent suspension: when one wheel passes over an obstruction, the shock is not transmitted to the opposite wheel—

thereby aiding steering and reducing chassis distortion; and the unsprung weight, reduced to a minimum, is confined to the weight of the wheel itself and does not include the axle, springs, and steering linkage—thereby improving riding qualities.

c. Of the several possible types of independent wheel suspensions, two have been predominantly used in the United States: parallel arm suspension and swinging arm suspension.

29. Parallel arm suspension.—*a*. An example of parallel arm, sometimes called parallelogram, suspension is shown in figure 20. The upper and lower control arms are pivoted to the frame in approximately parallel position. The steering knuckle support is mounted between the ends of these triangular-shaped control arms. The inner ends of the upper control arm are often attached to the shock absorber so it also acts as the shock absorber lever. The inner ends of the lower control arm are pivoted on a shaft having threaded bearings at each end and supported by brackets bolted to the bottom of the frame front cross member. When direct shock absorbers are used (fig. 21), the upper control arm is also pivoted on a shaft having threaded bushings and supported on the top of the frame front cross member.

b. The control arms allow the knuckle support, knuckle, and wheel to move vertically. The lower control arm is longer than the upper one to maintain the distance between the tires where they meet the roadway and to prevent sideslip from unduly scuffing and wearing the tires. Bushings are provided at both ends of the steering knuckle supports for the control arms. Eccentric threaded bushings are usually used on the upper end so the inclination of the steering knuckle pivot can be adjusted.

c. Coil springs are mounted between sheet metal cups riveted to the lower control arms and cups provided in the frame front cross member (fig. 21). Rubber bumpers are mounted on the outer end of the front cross member or on the control arms to prevent metal-to-metal contact as the coil spring compresses and rebounds. Laminated leaf springs may also be used for this type of suspension by mounting them transversely. Each wheel is then independently sprung on the ends of the leaf spring.

30. Swinging arm suspension.—*a*. The swinging arm type of suspension, also known as Dubonnet suspension, is designed as a unit. The entire suspension system (fig. 22) pivots on the steering knuckle pivot, the knuckle support being rigidly attached to the frame. The steering knuckle does not contain the wheel spindle as in the conventional design but is made integral with the rigid suspension housing.

The wheel spindle is contained on the end of a swinging arm, the other end of which is fastened to a cross shaft on the suspension housing. The swinging arm is mounted approximately horizontal and pivots

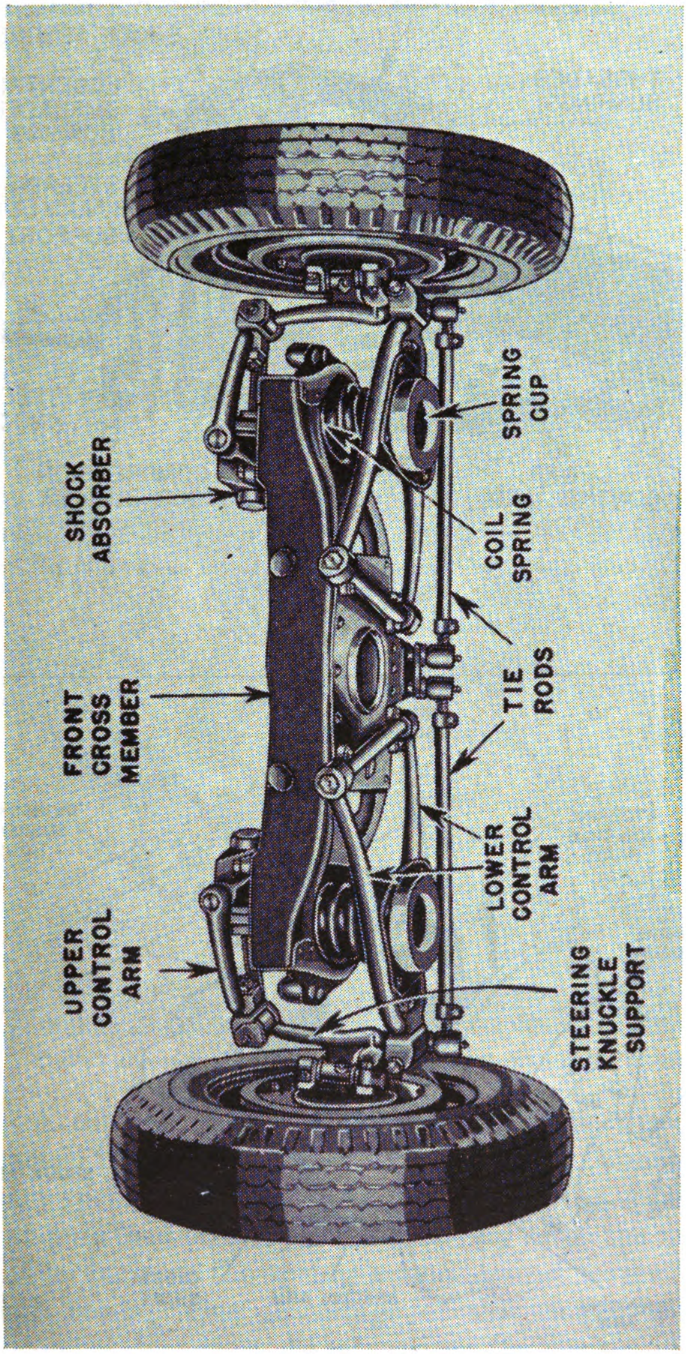

FIGURE 20.—Parallel arm suspension.

on the cross shaft to allow the wheel to move in a vertical arc. This cross shaft, which is mounted on roller bearings and sealed against

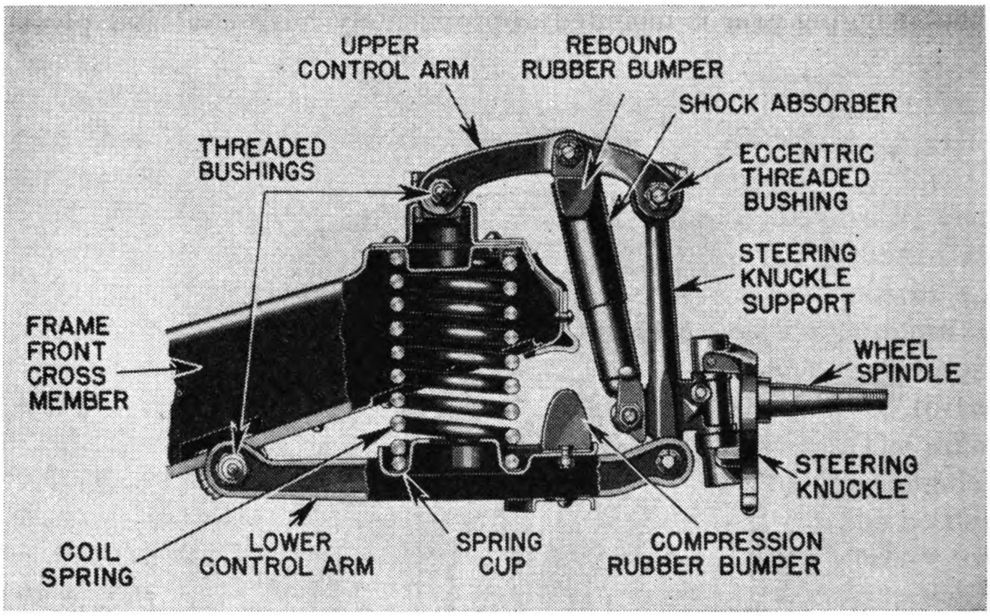

FIGURE 21.—Cross section of parallel arm suspension.

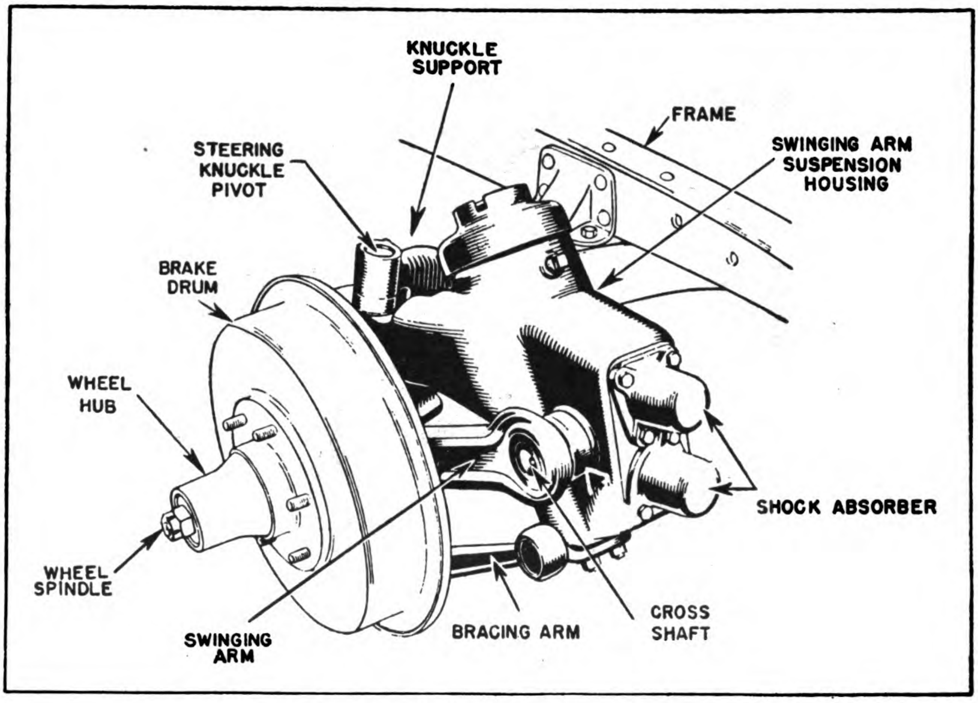

FIGURE 22.—Swinging arm suspension.

leakage, contains a spring lever inside the housing (fig. 23). The housing is filled with oil (shock absorber fluid) and must therefore be thoroughly sealed. This oil dampens spring action, acts as a lubricant for all internal parts, and is also used in the operation of the shock absorber contained on the housing.

b. The spring lever supports the lower spring seat on rollers and contains a double arm cam that operates the double acting shock absorber which is incorporated within the housing. The upper shock absorber cylinder checks compression and the lower cylinder checks

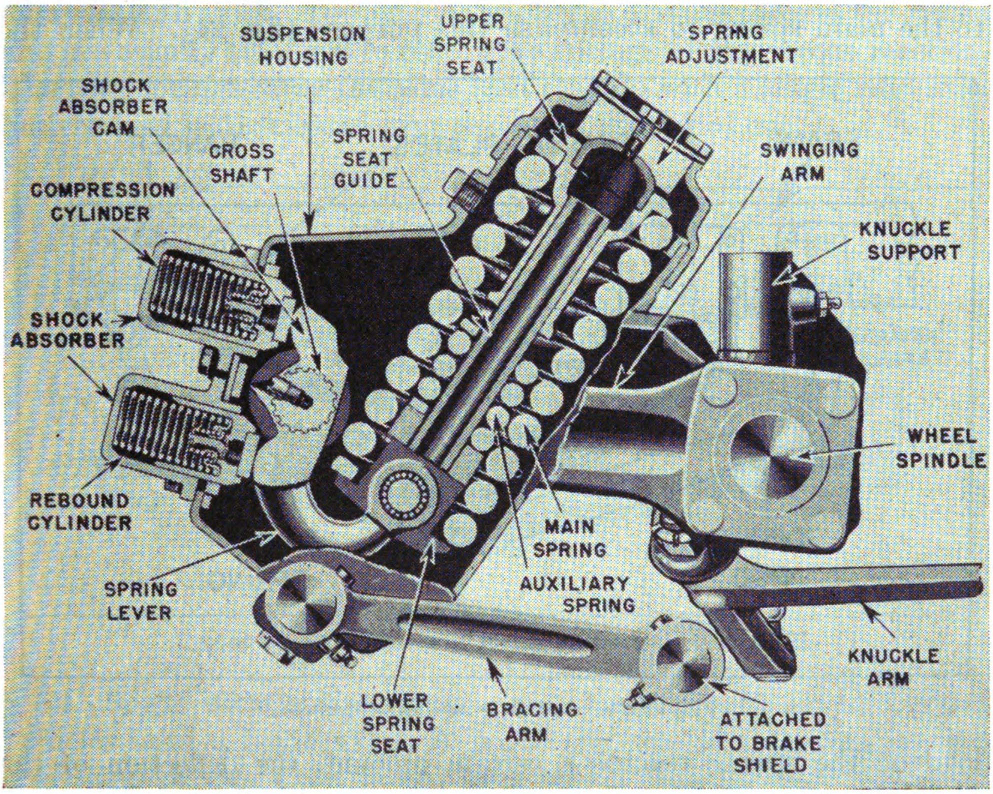

FIGURE 23.—Cross section of swinging arm suspension housing.

rebound. A tubular spring seat guide keeps the upper and lower spring seats in line as the spring is compressed. A main spring and an auxiliary spring are mounted between the spring seats. The upper spring seat puts load on the auxiliary spring after the main spring is compressed to increase the spring action against severe jolts received from rough roads. One advantage of this suspension is that the spring action can be adjusted by screwing the spring adjustment cap and altering the position of the upper spring seat.

c. A bracing arm is mounted parallel to the swinging arm and swings on bearings, one on the wheel brake shield and one attached to

the suspension housing. This bracing arm braces the wheel and prevents braking torque being transmitted through the coil spring. One disadvantage of this type of suspension is that the wheel alinement is affected when the springs are compressed, thus hindering the tendency of the wheels to straighten out when turning on a rough road or when the vehicle is overloaded.

31. Heavy vehicle suspension.—*a*. Several methods of spring suspension have been used for vehicles which carry widely varying loads in order to increase the load rating of the spring suspension as the load increases. Auxiliary springs are commonly used in addition to the main spring to accomplish this purpose (fig. 24). When the

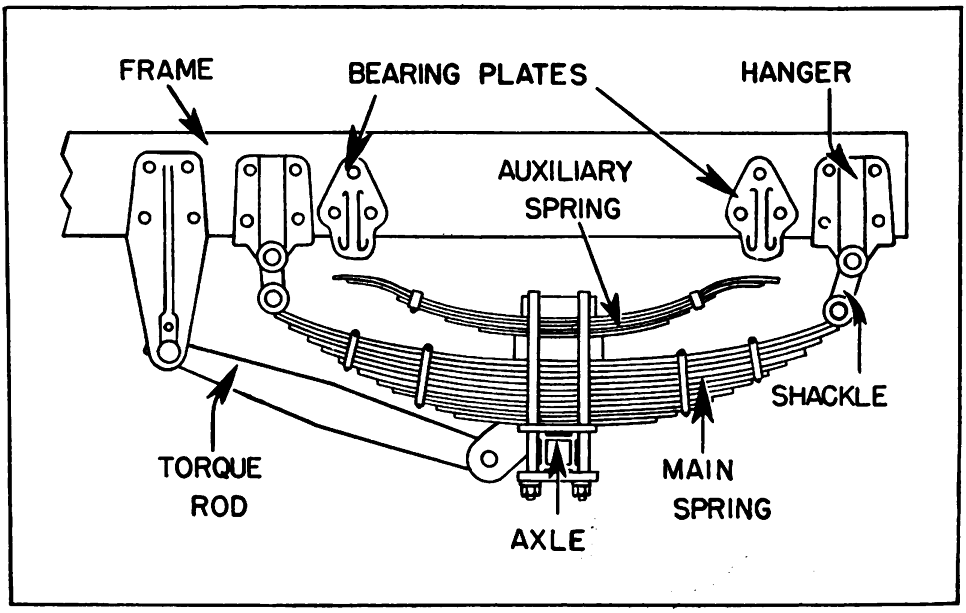

FIGURE 24.—Auxiliary spring suspension.

load on the spring reaches a certain amount, the deflection of the main spring brings the free ends of the auxiliary spring against bearing plates on the frame, or axle if the auxiliary spring is secured to the frame. From that point on, the two springs carry the load jointly and their load ratings are added. This enables the vehicle to carry heavy loads without unduly deflecting the wheels.

b. Another method of suspension that also provides a spring with variable load rating is shown in figure 25. The spring is made with flat ends which bear against curved bearing plates. With a light load, the springs make contact with the outer edges of the bearing plates, hence the effective length of the spring is comparatively large and it has a low load rating. Heavy loads deflect the spring, causing the points of contact to move toward the inner edges of the bearing plates

(fig. 25). Hence, the effective length of the spring becomes shorter, giving a higher load rating.

c. Two rear axles are used on numerous heavy vehicles to decrease the load on each rear wheel, to decrease the effect of road shocks, and to increase traction. A typical rear end on 6-wheel vehicles (fig. 26) consists of an axle mounted on each end of the rear springs, with the load of the vehicle applied at the center of the spring by means of a spring seat supported on the frame. The drive is applied to the forward of the two axles, with the rear axle trailing, or it is applied to both axles by means of an interaxle differential, insuring equal driving effort on both axles. Torque rods apply the driving force to the frame and are usually arranged to relieve the springs of any torque reaction. The rear springs carry the same load they do with a single rear axle, but the load is distributed over two axles instead of one.

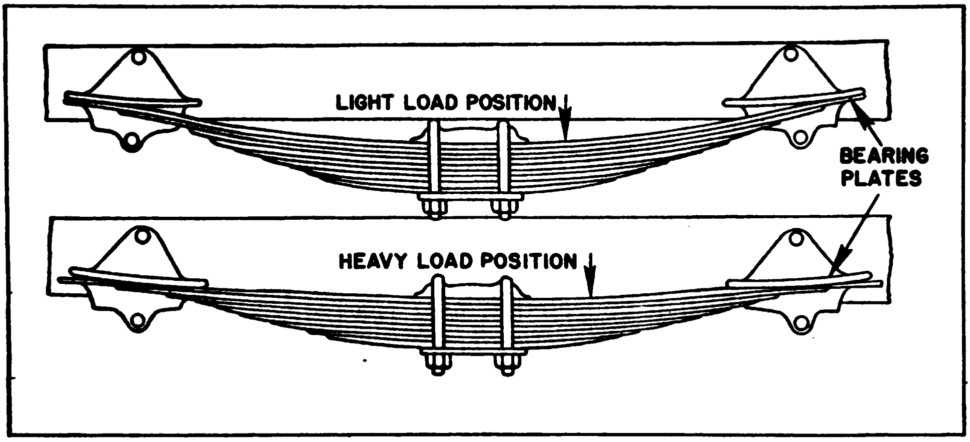

FIGURE 25.—Suspension of spring for variable load rating.

32. Bogie axle suspension.—*a.* A large proportion of 6-wheel vehicles have a bogie axle. A bogie (fig. 26) is a suspension unit consisting of two axles joined by a single cross support (trunnion axle) that acts as a pivot for the entire unit. The tubular trunnion axle is rigidly attached to the frame by two support brackets and girder cross member. The ends of each spring rest on hardened steel bearing plates on the two axle housings, the spring being supported on the vehicle frame by means of a spring seat on each end of the trunnion axle. Both springs are securely clamped on their spring seats by means of spring clips.

b. Both spring seats are mounted on a spindle on each end of the trunnion axle. Tapered roller bearings take side thrusts imposed on the spring and allow it to pivot easily. Springs with very high load rating must be used with this suspension because they carry the entire

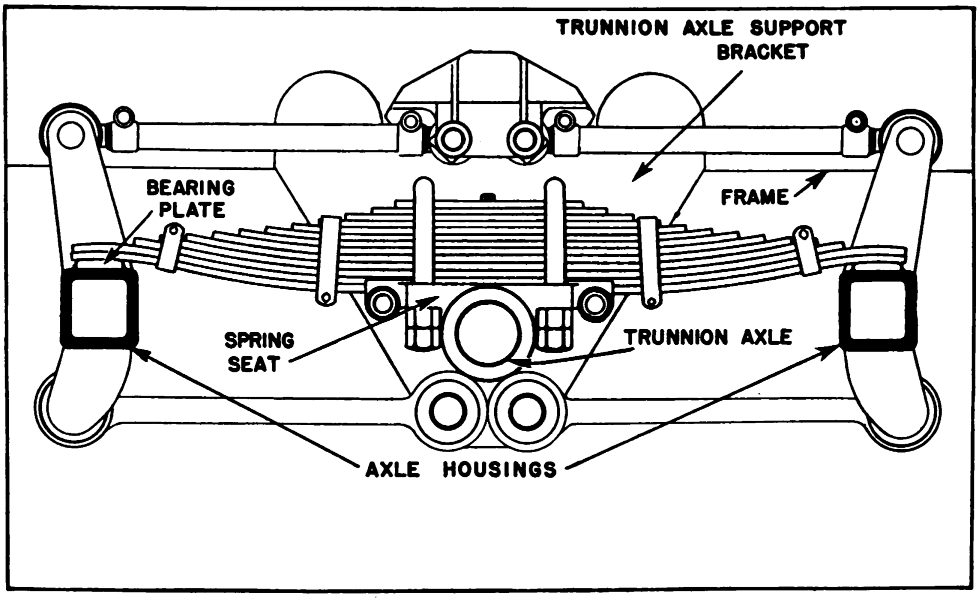

FIGURE 26.—Bogie axle suspension.

weight of the rear end. Mounting the springs on central pivots enables them to distribute half of the rear end load to each axle. As a result, the load on the rear of the vehicle is distributed over four wheels, allowing a vehicle to carry much heavier loads than a single rear axle vehicle without exceeding the safe tire load.

c. When one wheel is deflected from a road shock, the spring pivots about its center (fig. 27) so that both ends of the spring deflect to

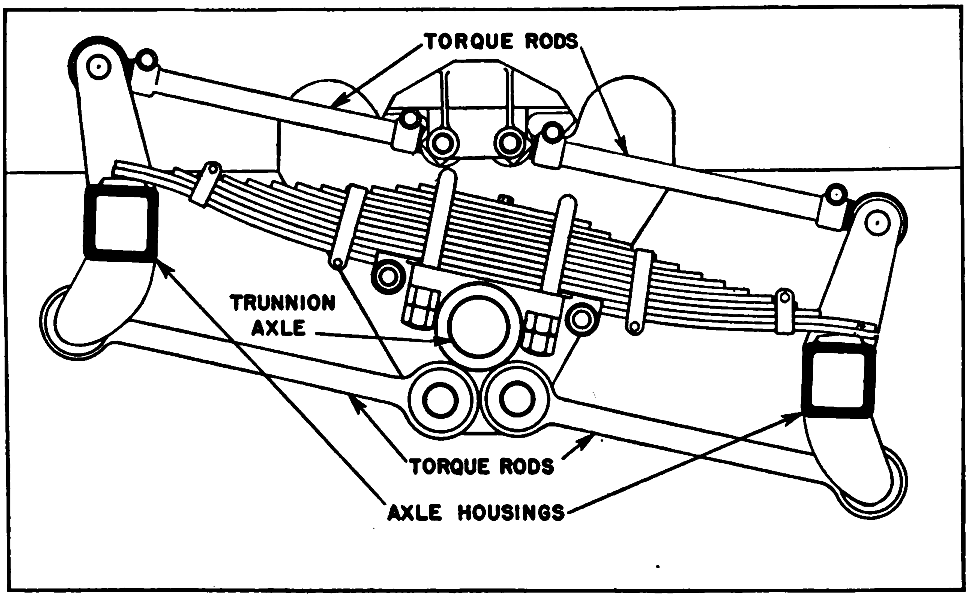

FIGURE 27.—Deflection of bogie axle suspension.

absorb the energy of the road shock rather than just one end. Thus, the effect of road shocks is cut in half. When only one axle is deflected up or down from its normal loaded position, the trunnion axle, and therefore the vehicle frame, is raised or lowered half of this deflection. In this manner, bogie axles reduce by one-half the impact or shock, not only to the vehicle chassis and cargo but also to the road surface.

d. The use of parallel torque rods (figs. 26 and 27) insures correct spacing and alinement of the two rear driving axles under all conditions of vehicle spring deflection. This feature prevents the transfer of weight from one axle to the other, or the tendency of one axle to "dig in" more than the other, and helps to avoid uneven tire wear and a jumping axle when the brakes are applied.

e. The only part requiring lubrication in this suspension unit is the spring seat spindle. The old lubricant should be completely removed every 6,000 miles and new wheel bearing grease packed in.

33. Torque rods.—*a.* Torque rods, also called torque arms and radius rods, are sometimes used to insure the accurate alinement of an axle with the frame and to relieve the springs of all stresses other than those due to the weight of the vehicle. One end of a torque rod is pivoted from a mounting bracket on the frame, and the other end rigidly mounted to the axle. Large rubber bushings are often used at both ends to eliminate metal-to-metal contact and to provide the desired cushioning.

b. A torque rod used with coil spring is shown in figure 11, and with a leaf spring shackled at both ends in figure 24. Torque placed on the axle when the brakes are applied is transmitted through the torque rods to the frame rather than through the springs to the frame.

34. Sway bars.—*a.* A vehicle tends to roll outward when turning, particularly at high speed. To prevent this roll, a sway bar or stabilizer is frequently used. It consists of a bar of alloy steel mounted across the chassis and secured to the frame through rubber bushings with arms on each end connected to the axle or independent suspension arms. When one side of the vehicle rises faster than the other, the twist set up in the bar reacts on the axle or independent suspension arms and tends to keep the frame level. If both sides rise equally, no twist is set up in the bar.

b. Sway bars may be mounted on either the front or the rear of a vehicle. They are usually used on the front end with independent front wheel suspension. The use of softer springs and independent front wheel suspension increases roll, therefore sturdy sway bars must be used.

Section V

STEERING SYSTEM

35. Steering methods.—*a.* In order to steer a vehicle the wheels must be changed from their straight-ahead position. A "fifth wheel" which serves as a central pivot for the entire front axle was an early method of steering (fig. 28). This method serves for vehicles that are pulled, such as trailers and horse-drawn vehicles, but it is not practical for self-propelled motor vehicles.

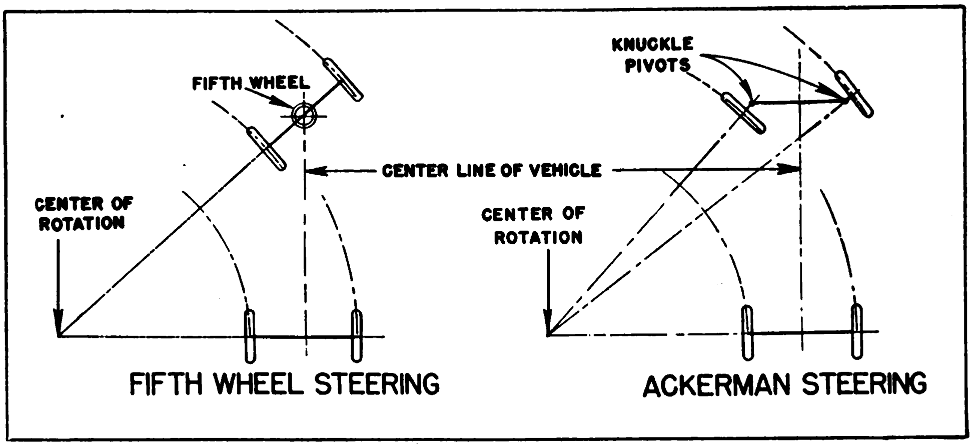

FIGURE 28.—Methods of steering.

b. The Ackerman system is used for automotive vehicles. In this method of steering, the front wheels are mounted on pivoted knuckles, and a steering linkage is used to tie the knuckles together so that the wheels rotate together about their pivots.

36. Steering linkage.—*a.* A steering knuckle arm is bolted and keyed to each steering knuckle. A 2-bolt fastening is sometimes used to reduce localization of stress. The knuckle arms are connected by a

tie rod (fig. 29) to tie the knuckles together. A steering gear connecting rod is attached to one knuckle arm for turning the steering knuckles about their pivots. This steering gear connecting rod is connected to the steering gear arm, commonly known as the Pitman arm, which is operated by the steering gear.

b. One of the steering knuckles may have two separate knuckle arms, one for the tie rod and the other for the steering gear connecting rod. A double arm (fig. 29) is frequently used to provide for these two connections. The steering gear connecting rod usually extends in the direction of the frame side members, though it may extend across the chassis.

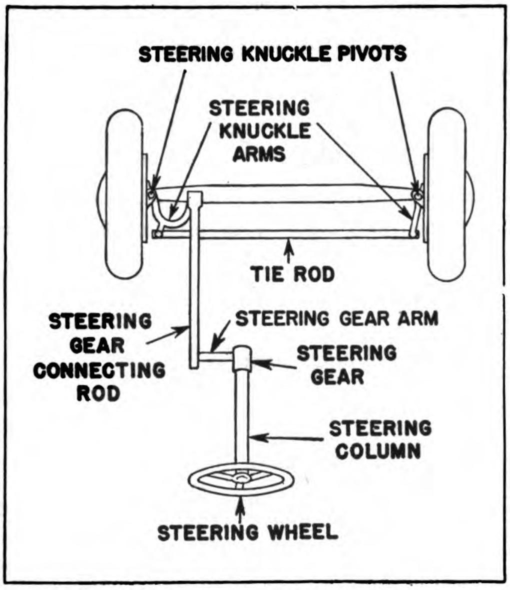

FIGURE 29.—Steering linkage.

c. The steering gear connecting rod is sometimes connected to an intermediate knuckle arm supported on the frame between the front wheels (fig. 30). Tie rods then extend from the intermediate knuckle arm to the two steering knuckles. This linkage is advantageous with parallel arm suspension, since each tie rod will move with its corresponding control arms so that vertical movement of the wheels does not disturb the wheel alinement or otherwise affect steering (fig. 20). The steering gear connecting rod is sometimes eliminated and the tie rods are connected directly to the steering gear arm.

37. Tie rod.—*a.* The tie rod is usually located behind the axle or the center line of the wheels, though it may also be in front. The length of the tie rod can be adjusted to keep the front wheels in proper alinement. It is usually tubular though it may be a solid rod,

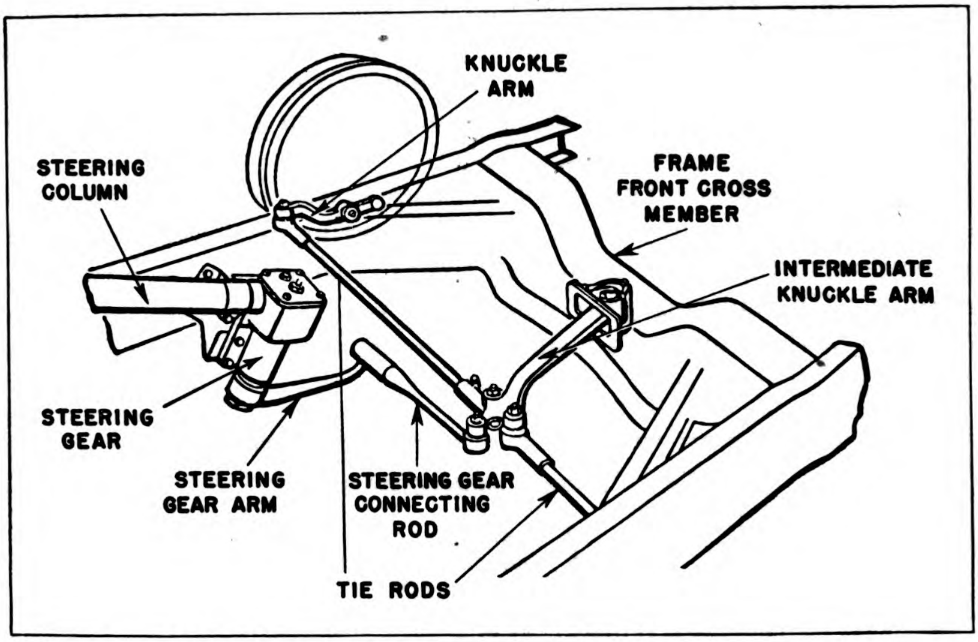

FIGURE 30.—Steering linkage with intermediate knuckle arm.

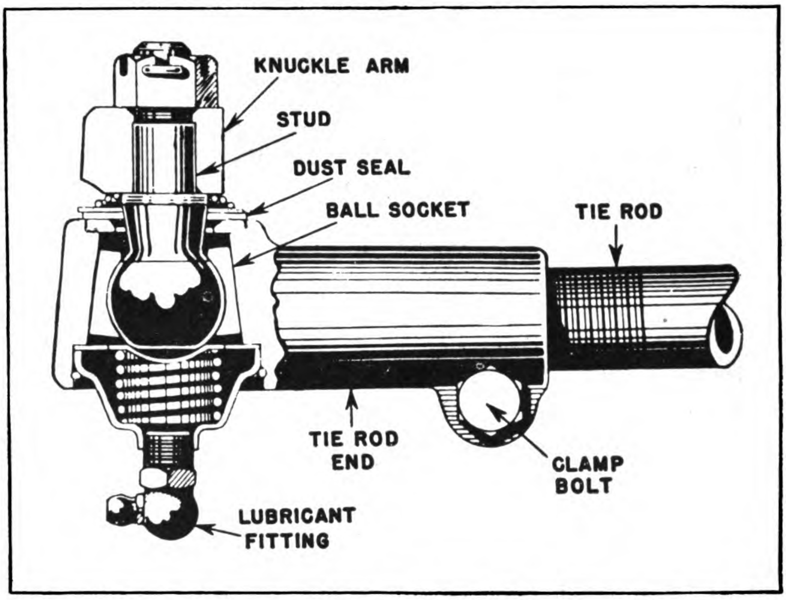

FIGURE 31.—Tie rod end.

and it has threads on which the tie rod ends are clamped (fig. 31). Thus, by turning the tie rod within the tie rod ends, the wheels can be tilted toward or away from each other to secure proper alinement.

b. Owing to the relative motion between the tie rod and its knuckle arms, it is necessary to have a swiveling connection between them. The tie rod end is usually fastened to the knuckle arm with a stud.

Some form of socket is provided within the tie rod end to hold the end of the stud, which is in the form of a ball or yoke and to allow movement between the knuckle arm and the tie rod. A lubricant fitting is usually provided to keep the ball and socket joint properly lubricated. A dust seal covers the tie rod end to prevent dust from entering the joint and loss of the lubricant.

38. Steering gear connecting rod.—*a.* The length of the steering gear connecting rod (fig. 29) should be such that the steering gear arm is vertical when the front wheels are straight ahead. Maximum leverage is then available for turning the wheels. The steering gear connecting rod, commonly termed the drag link, is made in tubular or rod form and provided with springs to cushion shocks and prevent their transmission to the steering gear.

b. A housing is provided on one end of the steering gear connecting rod to receive the ball end of the steering gear arm. Ball sockets, coiled springs, spring seats, and a screw plug secured by a cotter pin are inserted into this housing to hold the steering gear arm ball (fig. 32). Sometimes the slot through which the steering gear arm is in-

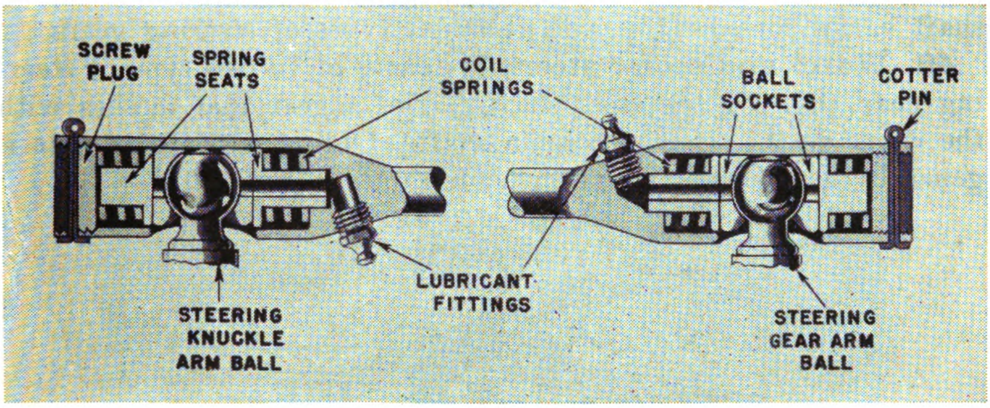

FIGURE 32.—Steering gear connecting rod.

serted extends the entire length of the housing, in which case the end of the housing has a screw cap. The end of the steering gear connecting rod attached to the steering knuckle arm is usually somewhat similar, though it may be made like a tie rod end.

c. Lubrication fittings are provided for each joint. Dust shields are fitted over the ball and socket joints to hold in the lubricant and to prevent dust entering the joint.

39. Steering gears.—*a.* A steering gear mounted on the end of the steering column operates the steering gear arm which moves the steering linkage. A steering gear should permit easy steering without requiring too many revolutions of the steering wheel to turn the

vehicle wheels from hard over one way to hard over the other. Steering gears provide reductions of 11 or 12 to 1 for light cars up to 18 to 1 or more for heavy trucks. This means the steering wheel must be turned from 2½ to 3½ complete revolutions (turning the steering gear arm through an arc of about 70°) to turn the wheels from hard over one way to hard over the other.

b. Steering gears are designed so that they will transmit motion very easily in one direction for steering and transmit practically no motion in the other direction to reduce to a minimum the transmission of shocks to the driver.

c. Some of the early steering gears were of the plain pinion and bevel gear type, some were of the planetary type, others were spur gears. Some form of modification of the worm and gear principle is now the most widely used.

d. The steering wheel is mounted on the top of the steering column and turns a shaft within the steering column. This shaft has a worm mounted on its lower end within the steering gear housing. The worm is geared to a cross shaft that contains the steering gear arm. The method of gearing the steering column shaft to the cross shaft varies considerably with different types of steering gears.

40. Worm and sector steering gear.—*a.* In this type of steering gear (fig. 33) the cross shaft carries a gear that meshes with the worm on the steering column shaft. Only a sector of a gear is generally used since it turns through an arc of only 70°.

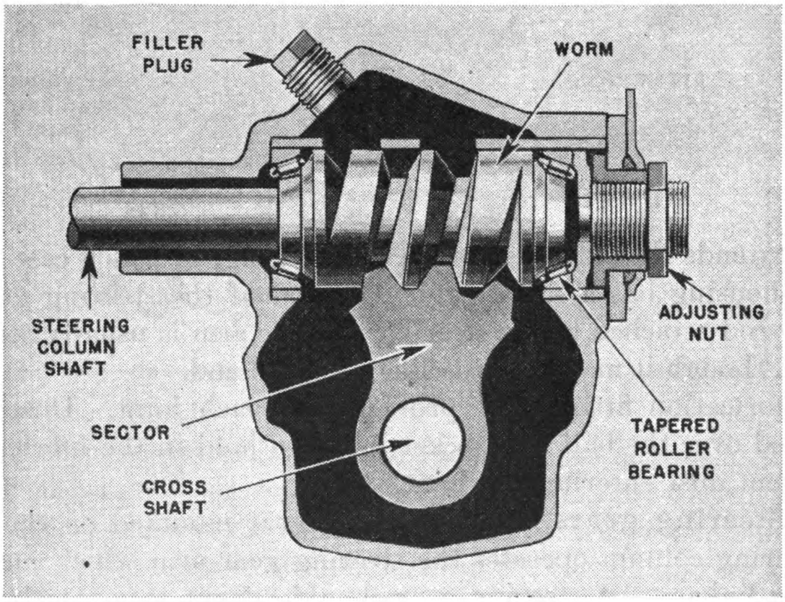

FIGURE 33.—Worm and sector steering gear.

b. The steering wheel turns the worm on the lower end of the steering column shaft, which rotates the sector and the cross shaft, carrying the steering gear arm. The worm is assembled between tapered roller bearings which take both thrust and load. An adjusting nut or plug is provided for adjusting the end play of the worm. Some means of adjusting the end play of the cross shaft is also provided.

41. Worm and roller steering gear.—*a.* The worm and roller type of steering gear (fig. 34) is quite similar to the worm and sector type except that a roller is supported by ball or roller bearings within the sector mounted on the cross shaft. These bearings assist in cutting down frictional losses. As the worm turns under

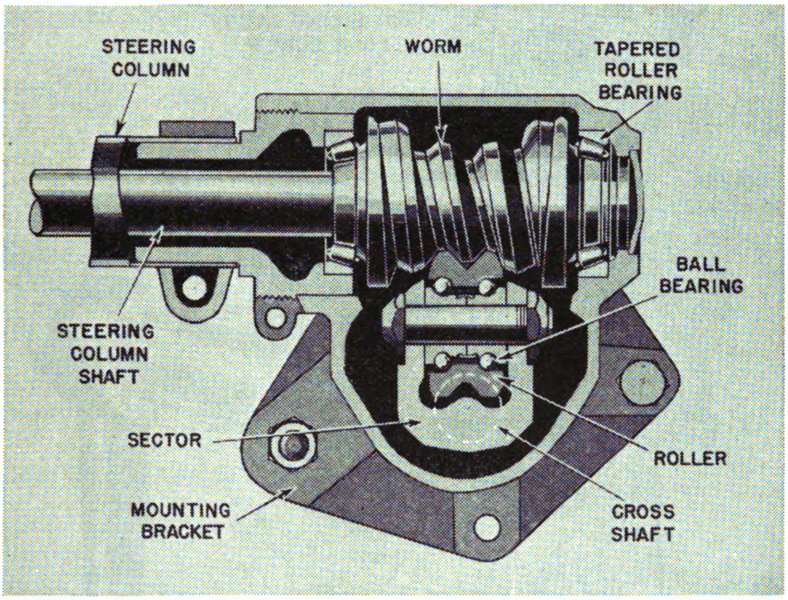

FIGURE 34.—Worm and roller steering gear.

control of the steering wheel, the roller turns with it but forces the sector and the cross shaft to rotate.

b. The hourglass form of the worm, that is, tapering from both ends to the center, affords better contact between the worm and roller at all positions. It provides a variable ratio to permit faster and more efficient steering. Variable ratio means that the ratio is larger at one position than another; therefore, the road wheels are turned faster at certain positions than at others. At the center or straight ahead position, the steering gear ratio is high, giving more mechanical advantage. However, as the wheels are cramped or turned to the side, the ratio decreases so that the action is much more rapid. This design is very helpful for parking or for maneuvering the vehicle.

42. Cam and lever steering gear.—*a.* A cam and lever type steering gear in which the worm is known as a cam is shown in figure 35. The cross shaft carries a lever on the inner end. This lever carries a stud which engages with the cam. The stud may be integral or mounted on roller bearings. Roller bearings reduce friction and allow easier steering. As the steering wheel is turned, the stud moves up and down on the cam and carries the lever with it to rotate the cross shaft.

b. The lever moves more rapidly as it nears either end of the cam since it is then at a greater angle with it. Maximum leverage occurs

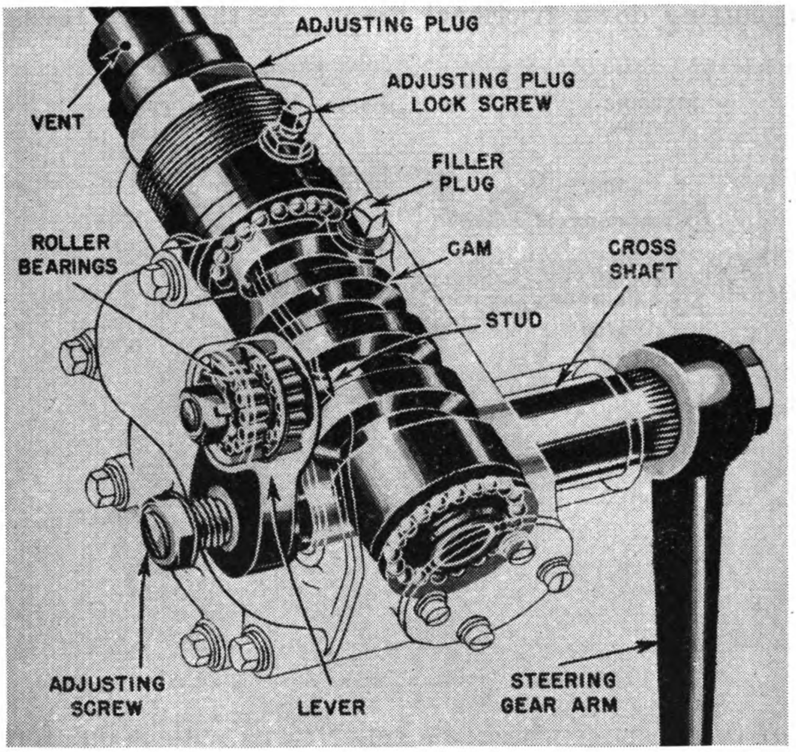

FIGURE 35.—Cam and lever steering gear.

at the straight ahead position when the lever is at right angles to the cam. This makes the initial turning of the wheels easier. It is seen, therefore, that a variable ratio is obtained with cam and lever steering. A twin lever provided with two studs is used on a recent design for heavier vehicles to obtain more stable and positive steering.

43. Worm and nut steering gear.—*a.* Another form of steering gear is the worm and nut, which is made in several different combinations. A nut is meshed with the worm and screws up and down on it. The nut may operate the steering gear arm directly through a lever or through a sector on the cross shaft.

b. An example of the recirculating ball type of the worm and nut steering gear is shown in figure 36. In this steering gear the nut, which is in the form of a sleeve block, is mounted on a continuous row of balls on the worm to reduce friction. This ball nut is fitted with tubular ball guides to return the balls diagonally across the nut to recirculate them as the nut moves up and down on the worm. With this design, the nut is moved on the worm by rolling instead of sliding contact. Turning the worm moves the nut and forces the sector and the cross shaft to turn.

44. Steering gear lubrication.—*a.* The recommendations of the steering gear manufacturers as to the proper lubricant should be

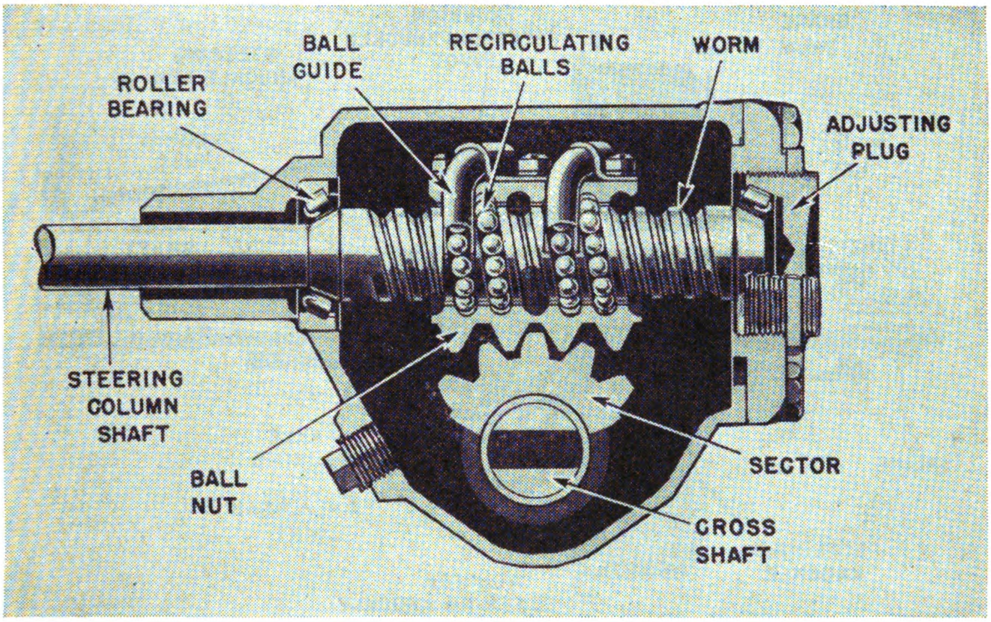

FIGURE 36.—Worm and nut steering gear (recirculating ball type).

carried out. Some gears are lubricated with a light chassis grease while others use a gear lubricant. Special steering gear lubricants are provided by most oil companies. In general these lubricants are heavy oils that have a minimum change in viscosity over extreme temperature ranges and have very little tendency to become thick and gummy.

b. The steering gear should be checked every 1,000 miles and the proper lubricant added if required. Care should be taken to avoid overfilling the steering gear housing because room must be allowed for expansion. A vent is usually provided to allow for expansion.

45. Four-wheel driving and steering.—*a.* Four-wheel drive—a construction in which all four wheels of the vehicle drive, and some-

times steer—is used on many military vehicles. A typical construction for a wheel that drives and steers is illustrated in figure 37. A universal joint is used at the end of the axle shaft so that the wheel will be free to pivot at the end of the axle as well as be driven through the axle. The end of the axle housing encloses this universal joint and is provided with vertical trunnion pins which act as a steering knuckle pivot. The wheels, mounted on steering knuckles attached to these trunnion pivots, are thus free to turn about the pivots at the same time that they are driven through universal joints on the inner axle shaft. Steering knuckle arms are mounted on the steering

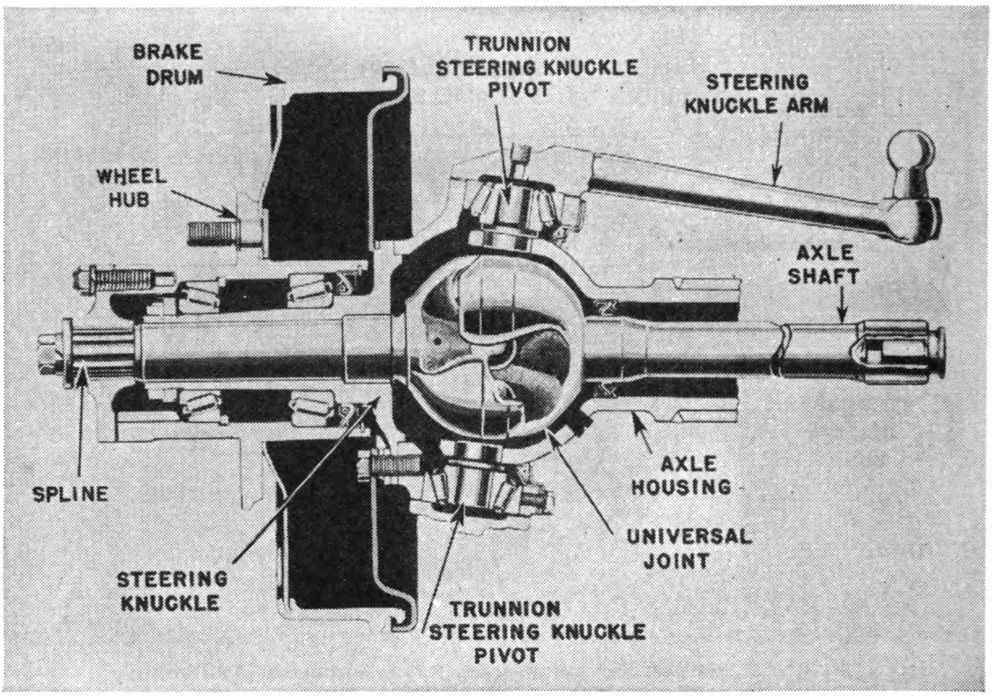

FIGURE 37.—Construction of an axle end for a wheel that drives and steers.

knuckles so that the wheels can be turned about the trunnion steering knuckle pivots by the steering linkage.

b. All four wheels can be steered from the steering wheel by connecting the steering linkage of these wheels to the steering gear arm. The rear wheels are connected together by knuckle arms and a tie rod so that the steering linkage for both the front and rear wheels is similar to that already described for 2-wheel steering. Since the rear wheels must be turned in the opposite direction to the front wheels to travel in the same arcs about the center of rotation, the steering gear connecting rods to the front and rear wheel steering linkage cannot be directly connected to the steering gear arm. The

steering gear connecting rod to the front wheels must move forward while the steering gear connecting rod to the rear wheel moves rearward, and vice versa. To accomplish this, an intermediate steering gear arm (fig. 38) is pivoted on the frame side member near the middle of the vehicle. The steering gear connecting rods are connected to opposite ends of this arm so that, as it is turned by direct connection to the steering gear arm (by means of an intermediate steering gear connecting rod), the front and rear steering gear connecting rods are moved in opposite directions.

c. With this hook-up, the movement of the steering wheel in any given direction turns the rear wheels so that they follow the same arcs as the front wheels. The vehicles thus make the desired turn in one-half the turning radius of 2-wheel steering.

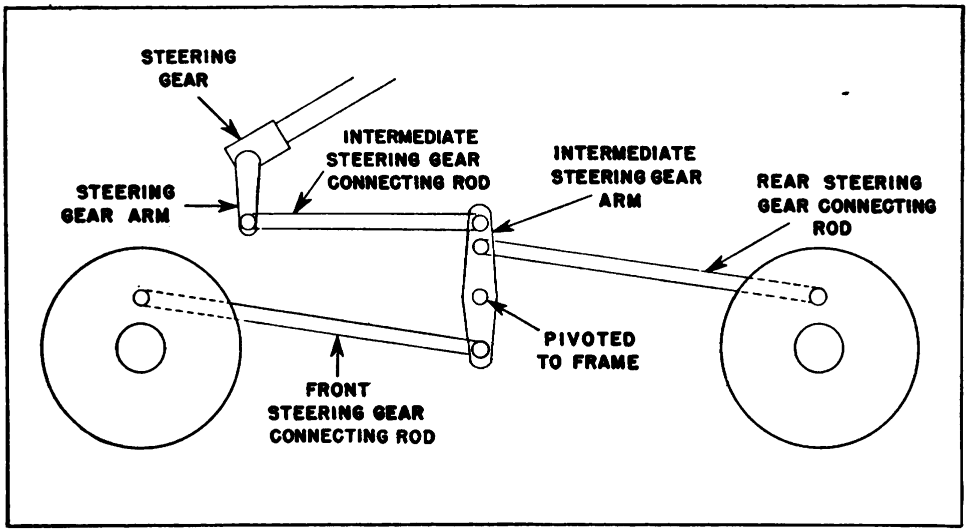

FIGURE 38.—Four-wheel steering hook-up.

46. Air steering.—*a.* Heavy vehicles are difficult to steer because large loads on the tires increase their turning resistance. This difficulty cannot be overcome satisfactorily by using a steering gear with a very high reduction ratio, because it would require numerous revolutions of the steering wheel to turn the vehicle wheels. Some form of power steering to aid the driver in steering the heavier vehicles is therefore desirable. Air steering is a very satisfactory method of power steering, because the heavier vehicles on which it would be used usually have an air-braking system from which the air pressure can be obtained. If there is no air-braking system, an air compressor and reservoir are required to obtain the necessary air pressue.

b. Air-steering control (fig. 39) consists primarily of three major units: a combination of levers mounted on the steering gear cross shaft; two control valves; and an air cylinder containing a double

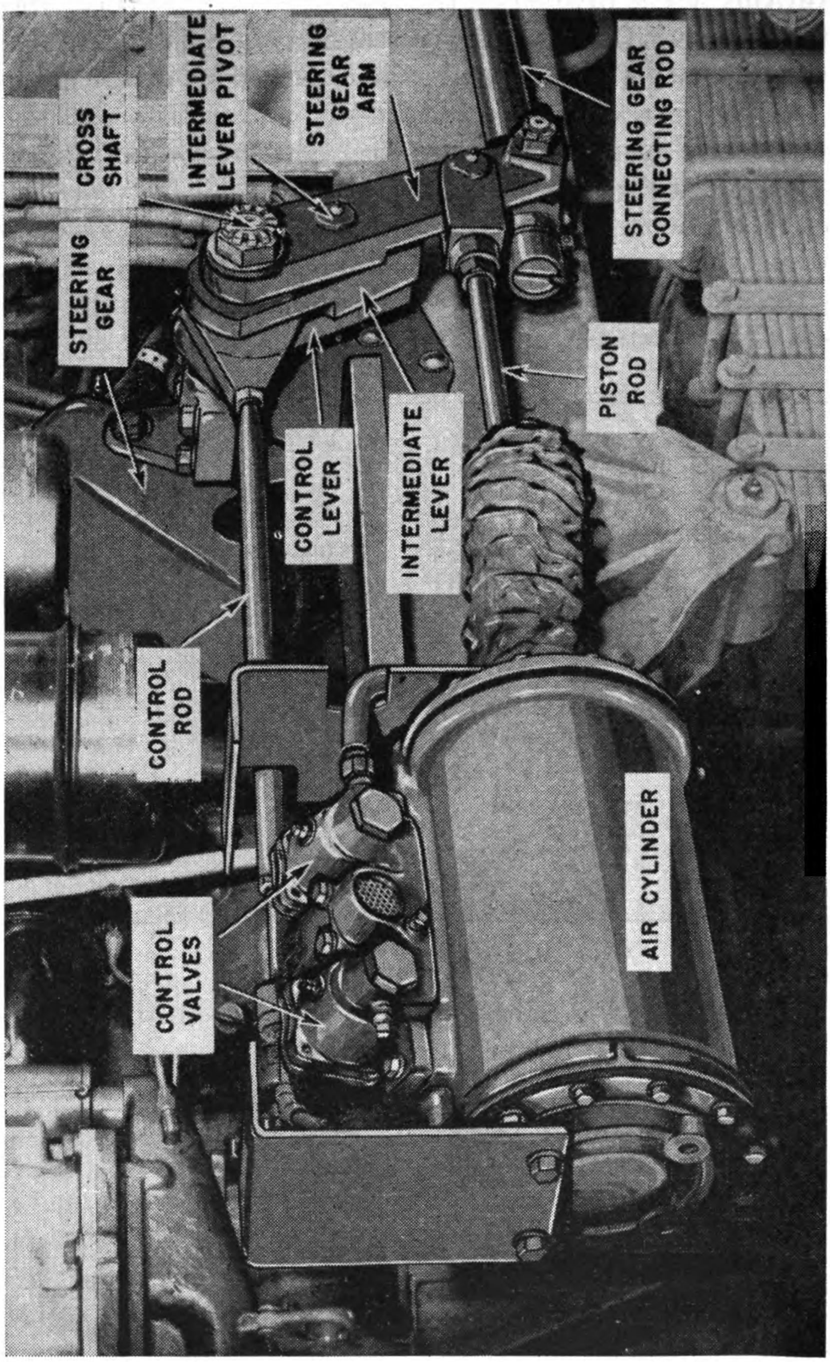

FIGURE 39.—Air-steering control.

acting piston. The control valves are mounted directly on the air cylinder, each valve controlling one side of the cylinder. The air

pressure delivered from the air line to the cylinder is proportional to the force applied on top of the valve piston plunger by the control rod (fig. 40). The valves are actuated by a rocker arm so that air is delivered to one side of the cylinder at a time. These valves are so adjusted that the air can be exhausted from both sides of the cylinder simultaneously, but air pressure can be delivered to only one side at a time.

c. Three levers (fig. 39) are mounted on the steering gear cross shaft: the control lever, the intermediate lever, and steering gear

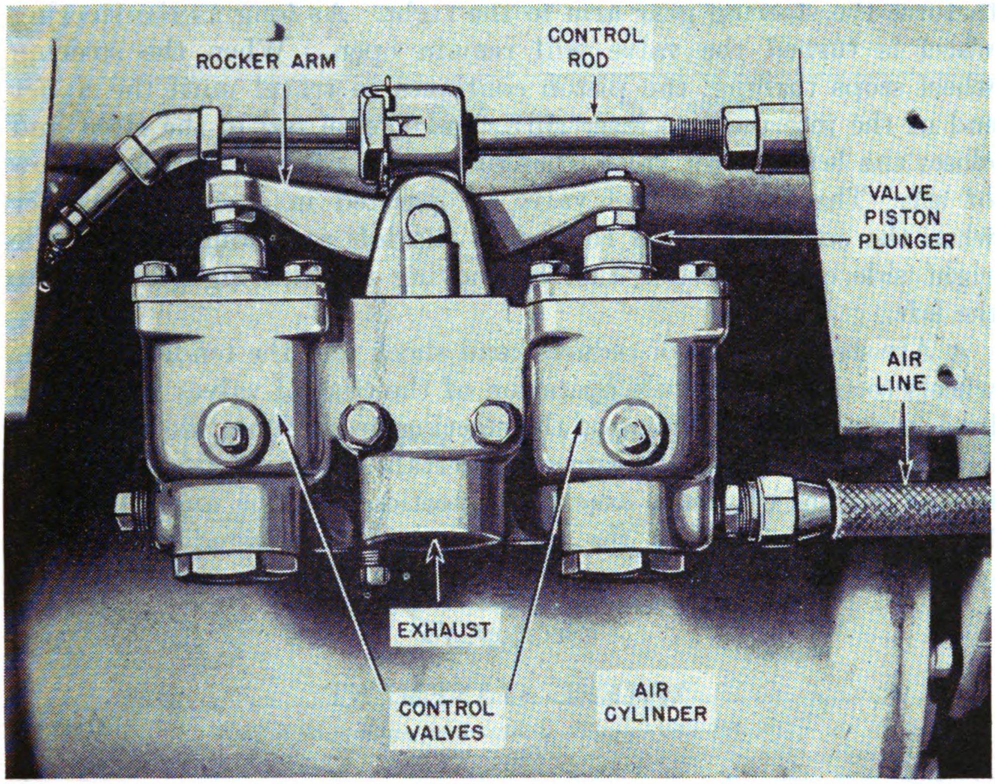

FIGURE 40.—Top view of air cylinder control valves.

arm. The control lever is fixed directly to the steering gear cross shaft. The intermediate lever is pivoted near its center to the steering gear arm and at its lower end to the control lever. The upper end of the intermediate lever is bored slightly larger than the cross shaft, so that free motion is obtained, and is connected by a yoke to the control rod. The steering gear connecting rod is connected to the end of the steering gear arm, and the cylinder piston rod is connected just above it.

d. Turning the steering wheel turns the cross shaft and rotates the control lever in one direction or the other. If the control lever is moved to the right, the upper end of the intermediate lever, which is free, moves to the left, because the intermediate lever is pivoted on the steering gear arm. This causes the control rod to move to the left and, through the rocker arm (fig. 40), to exert pressure on the plunger of the left control valve, which is connected to the left side of the cylinder. Thus, air under pressure will be admitted to the cylinder until the force on the piston in the cylinder is equivalent to the turning resistance of the wheels, and will move the piston rod to force the steering gear arm to the right. As long as the steering wheel is turned the valve will remain open. When the steering wheel stops turning, the piston continues to travel until the upper end of the intermediate lever shifts the control rod to the right and closes the left control valve, thereby cutting off any additional flow of air. The right control valve is operated in a similar manner when the control lever is rotated to the left and admits air to the right side of the piston, thereby moving the steering gear arm to the left.

e. Air-steering control reduces road shock and the tendency of the wheels to shimmy because operation of the control valves is reversed by a very slight movement of the steering gear connecting rod. The driver, in steering, must overcome a certain resistance predetermined by the system of levers exactly proportional to the angle of turn. If the air pressure fails the wheels can still be steered by physical effort.

SECTION VI

WHEEL ALINEMENT

47. General.—*a.* Wheel alinement is the mechanics of keeping all the interrelated parts of the front wheels properly adjusted. This is done to prevent pulling to the right or left, scuffed tires, wander, shimmy, tramp, and hard steering.

b. The front end assembly of the modern motor vehicle is one of the most remarkable engineering accomplishments on the entire vehicle. The steering linkage must be designed so the wheels will have the

proper toe-out when turning. The steering knuckle pivots are castered, or tilted backward, and also cambered, or tilted inward, to give a steering knuckle pivot inclination. The wheels are cambered, or tilted outward, and are also "toed-in" at the front.

c. Thus five main factors, all of them related and dependent upon each other, determine proper wheel alinement—

(1) Toe-out.
(2) Caster.
(3) Camber.
(4) Pivot inclination.
(5) Toe-in.

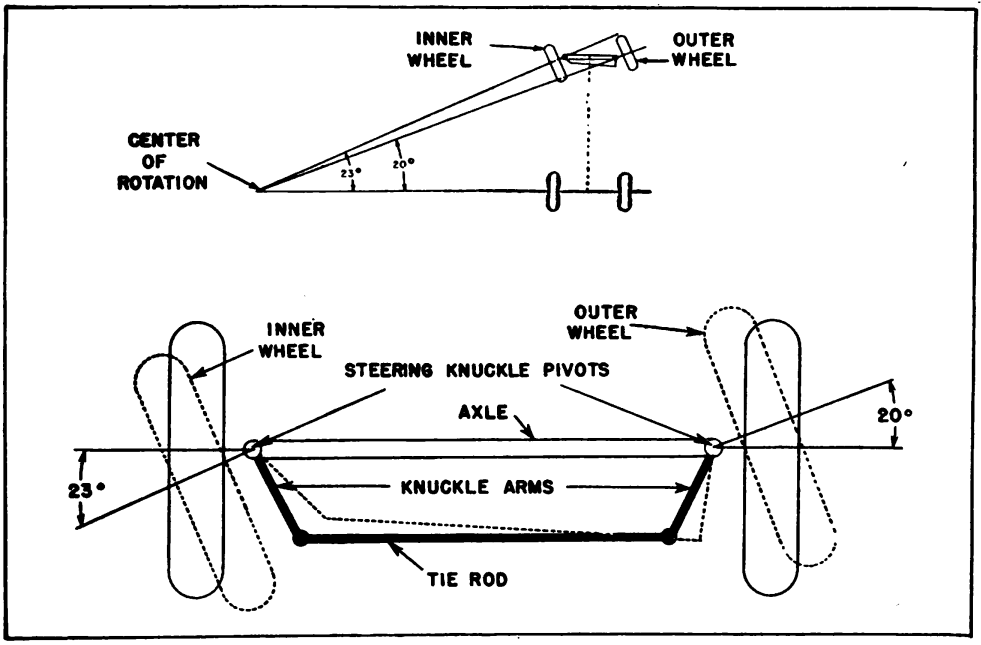

FIGURE 41.—Steering geometry (illustrating toe-out).

48. Steering geometry.—*a*. Most of the troubles connected with the front end assembly of the modern motor vehicle result because each front wheel is separately pivoted on a steering knuckle ("Ackerman" steering) instead of both being pivoted from one point ("fifth wheel" steering). Because of this construction, the front wheels, when a vehicle is making a turn, are not on the same radius line, drawn from the center of rotation. (See upper diagram, fig. 41.) Since each wheel should be at right angles to its radius line, it is necessary for the front wheels to assume a toed-out position when rounding curves. If they do not, the tires slip which causes excessive tire wear.

b. The knuckle arms are tilted toward each other (fig. 41) so that when the wheels are turned they will no longer be parallel, the inner

wheel (the one closer to the center of rotation) being turned more than the outer wheel so it will travel in a smaller radius. This difference, termed "toe-out," in the turning radius of the two wheels due to steering geometry is usually specified as the number of degrees over 20° through which the inner wheel is turned when the outer wheel is turned 20°, that is, 3° in figure 41.

c. Analysis of this linkage will show that even though the wheels are turned different amounts, they do not have an exactly common center of rotation. All steering designs are necessarily close approximations to the ideal condition. They attempt to bring the center of rotation of both wheels close to the vehicle's center of rotation under

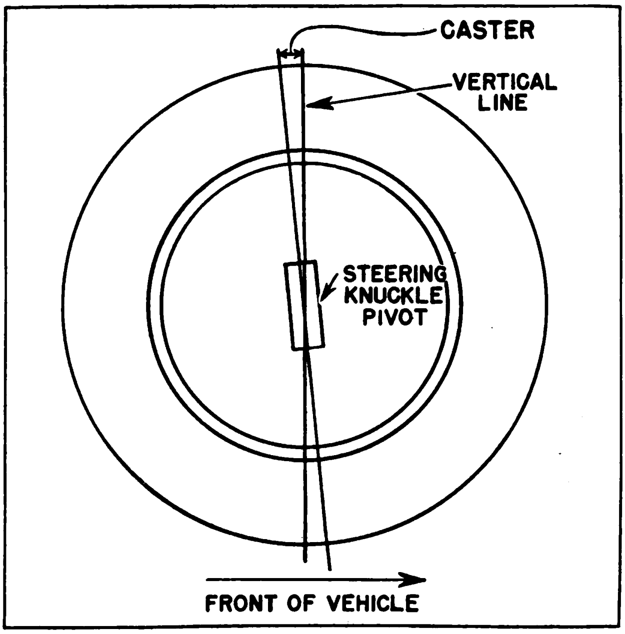

FIGURE 42.—Positive caster.

all turning conditions. The exact amount of inclination of the steering knuckle arms toward each other is very carefully studied on any particular design.

49. Caster.—*a.* Caster is the amount, measured in degrees, that the steering knuckle pivots are tilted forward or backward from the vertical when viewed from the side (fig. 42). Caster tends to keep the front wheels pointed straight ahead, hence making it easy to return the wheels to a straight ahead position after a turn has been made. The principle is exactly the same as that used in tilting the front fork of a bicycle, which makes it possible to ride the bicycle without grasping the handle bars. Part of the effort applied for turning castered wheels out of the straight ahead position slightly

raises the front end of the vehicle upward. Consequently, when the steering gear is released, the weight of the vehicle forces the front end down and straightens the wheels. Caster is designated as positive for backward tilt and negative for forward tilt of the steering knuckle pivots.

b. With axle suspension, caster may be obtained by inserting a thin wedge or shim between the axle and the spring. The axle can be made so that the supports for the steering knuckle pivots are tilted from the vertical. In parallel arm suspension, caster is obtained by mounting the steering knuckle support in the control arms so that it is tilted the desired amount. If the axis of the steering knuckle pivot is extended, it must strike the ground ahead or behind the point where the tire meets the ground. The caster varies from ½° to 3° on modern vehicles.

50. Camber.—*a.* Wheel camber (fig. 43) is the angle made by the wheel with the vertical when it is in the straight ahead position. Cambered wheels are closer together at the bottom than they are at the top. For many years, front wheel camber as great as 3° has been used. For driving on crowned roads, this camber permitted better rolling contact by bringing the wheel perpendicular to the road and made steering easier. In recent years, the use of flat roads and low pressure tires has led to a decrease in camber. If the vehicle should run on a flat road and had no lost motion at the bearings, zero camber would be ideal; but it is not practicable to build front axles with zero camber because of the possible accumulation of bearing clearances and the slight deflection of the axle under the vehicle load. Therefore, a camber of about 1° is recommended at present. Excessive camber causes continual slippage of the tire on the road, because each wheel tries to follow a path away from that traveled by the vehicle. This is due to the fact that a cambered wheel tends to roll like a cone because its axis is not horizontal.

b. Camber is obtained by tilting the wheel spindle slightly downward on the steering knuckle. Camber can be adjusted in parallel arm suspension by using eccentric bushings to change the angle at which the steering knuckle support is mounted between the control arms.

51. Pivot inclination.—*a.* Pivot inclination is the amount in degrees that the steering knuckle pivots are tilted sideways toward the center of the vehicle (fig. 43). Inclination of the steering knuckle pivots tends to keep the wheel spindles pointed outward, in line with the axle, just as caster tends to keep the wheels of a vehicle pointed

straight ahead. The effect is the same and will also result in easier steering.

b. Setting the steering knuckle pivot at an angle causes the pivot axis to meet the ground close to the center of tire contact (fig. 43). The wheel, therefore, has a small turning radius so that it will be easy to turn and will roll in a very small arc on the ground. Too much inclination makes it difficult to park a vehicle because, if the intersection of the pivot axis with the ground falls at the center of tire contact with the ground, the tire slides rather than rolls when

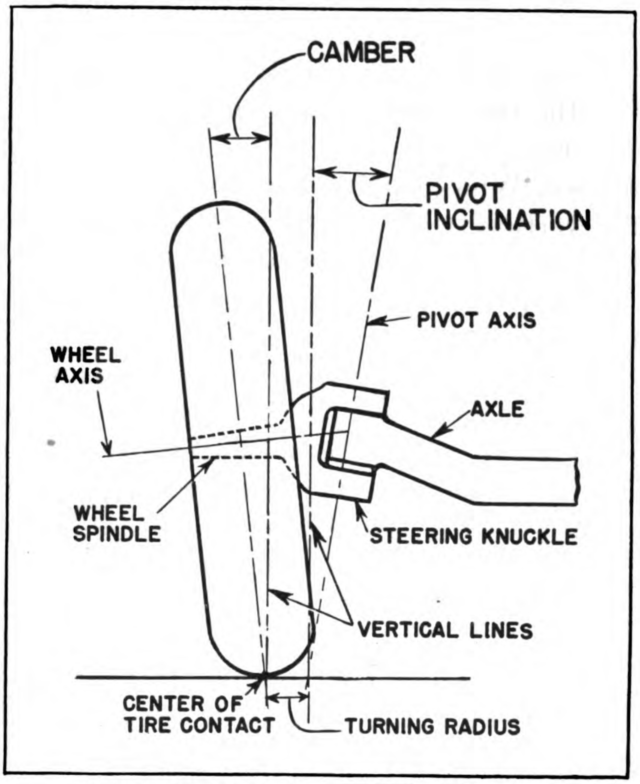

FIGURE 43.—Camber and pivot inclination.

the wheel is turned on a stationary vehicle. Pivot inclination is usually from 3° to 7°.

c. Careful distinction should be made between camber and pivot inclination (fig. 43). They are closely related and dependent on each other. Wheels with large camber require large pivot inclination and those with small camber small pivot inclination. Pivot inclination allows the front wheel brakes to be applied with little effect on steering.

52. Toe-in.—*a.* Toe-in (fig. 44) is the amount in inches that the wheels point in; that is, the distance between the front wheels is

less at the front, *A*, than it is at the rear, *B*, figure 44. Toe-in and camber are definitely related and depend upon the crown of the road. For a flat road, experience indicates that a desirable condition is to have zero camber and zero toe-in. However, such a condition is difficult to maintain.

b. Toe-in balances the effect of camber on the tires. A cambered wheel is not vertical to a flat road, and the axis of the wheel, if prolonged, will intersect the road at some point to the side of the vehicle. The natural tendency of the wheel then is to rotate like a cone about this point. If both front wheels are forced to follow a straight path by the motion of the vehicle, there is a continual tendency for the tires to slip away from each other. Toed-in wheels tend to travel toward each other and counteract this condition. By properly relating camber and toe-in, tire wear is reduced

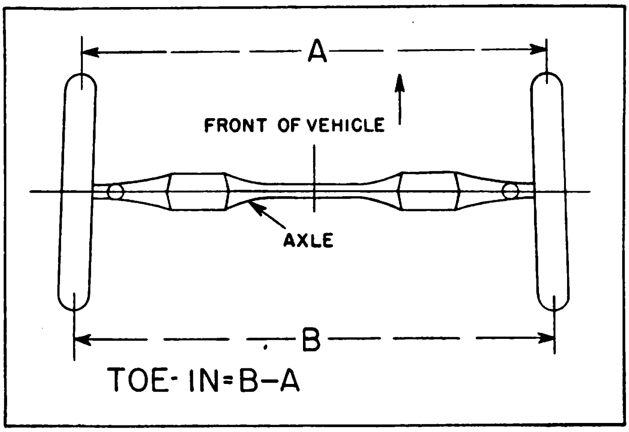

FIGURE 44.—Toe-in.

to a minimum, the motion of the wheel is balanced between two opposing tendencies, and pull on the steering mechanism is reduced. The amount of toe-in is adjustable by changing the length of the tie rod.

SECTION VII

WHEELS, RIMS, AND TIRES

53. Wheels.—*a. General.*—The wheels support the weight of a vehicle, resist the side strains created by a turning vehicle, and transmit the driving and braking torques for propelling and retarding it. A well-balanced construction is very important, particularly with the high speeds developed today. A slight unbalance will result in a bouncing wheel at high speeds and cause uneven tire wear. The addition of small balance weights on the light side of the wheel is sometimes necessary to remedy this unbalanced condition.

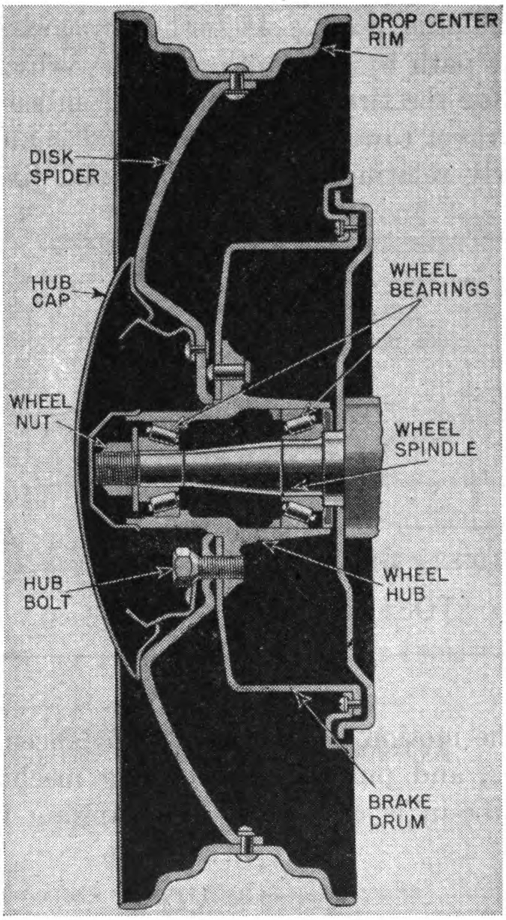

FIGURE 45.—Cross section of a wheel.

b. Parts.—The essential parts of a wheel are the hub, which is mounted on the wheel spindle; and the outer rim, on which a tire is mounted (fig. 45). These parts are connected by a spider made of a disk or spokes. A brake drum is also contained on the wheel and is usually attached to the hub. Wheel construction varies with different types of vehicles.

c. Disk wheels.—(1) Practically all passenger cars now use disk wheels (fig. 46). A steel disk spider is riveted or welded to the rim and bolted to the wheel hub. Five or six heat-treated steel bolts are used to fasten securely the disk to the hub. To prevent the rotation of the wheel tending to loosen these bolts, the wheels on the right side are frequently fastened with right-hand thread bolts and those on the left side with left-hand thread bolts. To provide a pleasing appearance, hub caps are snapped onto the disk by means of snap springs provided on the disk. The disk is dished to give it flexibility. This type of wheel is strong and easy to clean. Slots or holes are cut into the disk near the rim to allow circulating air to cool the brake drum.

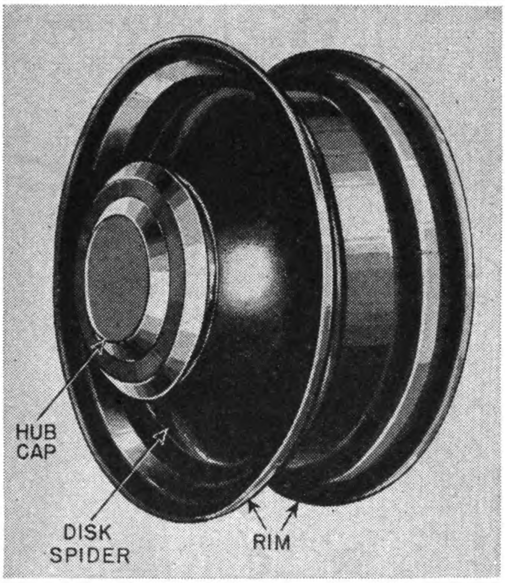

FIGURE 46.—Passenger car disk wheel.

(2) On heavier vehicles the disk spider is a steel forging and has sections of the disk cut away so that the wheel seems to have flat spokes (fig. 47). Ten or more hub bolts are used for fastening the disk to the hub on large vehicles.

d. Spoke wheels.—(1) The wheels of earlier motor vehicles were made with wooden spokes. These have become obsolete because of the increased strength and decreased weight obtained with steel construction. Wire-spoked wheels were used considerably for passenger cars but have been replaced by disk wheels which are easier to manufacture. Wire-spoked wheels are light in proportion to their strength, flexible and easy on tires, but are expensive and difficult to clean. With the use of smaller wheels and larger brake drums,

the wire spokes became short stiff struts and the advantages of this construction disappeared.

(2) Several types of spoke wheels made of malleable or cast steel are used for heavier vehicles (fig. 48). The spokes are usually hollow and joined to form a spider that fits over the wheel hub. Pressed-steel felloes are sometimes fitted over the spokes for supporting the rim. The rim is fastened on the spoke spider by clamps provided on the ends of the spokes.

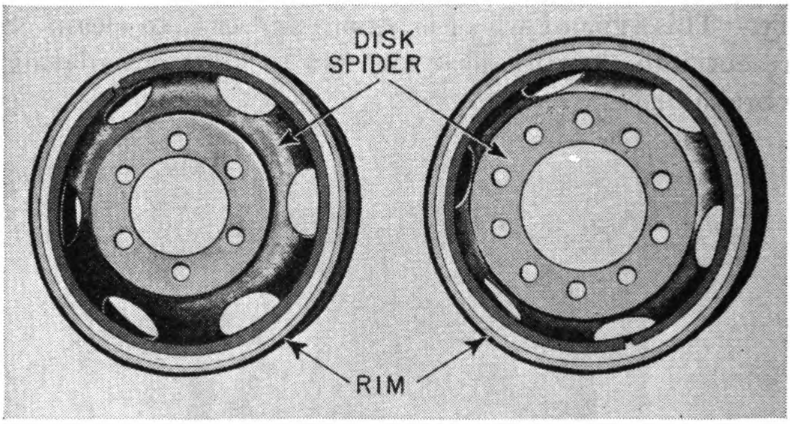

FIGURE 47.—Truck disk wheels.

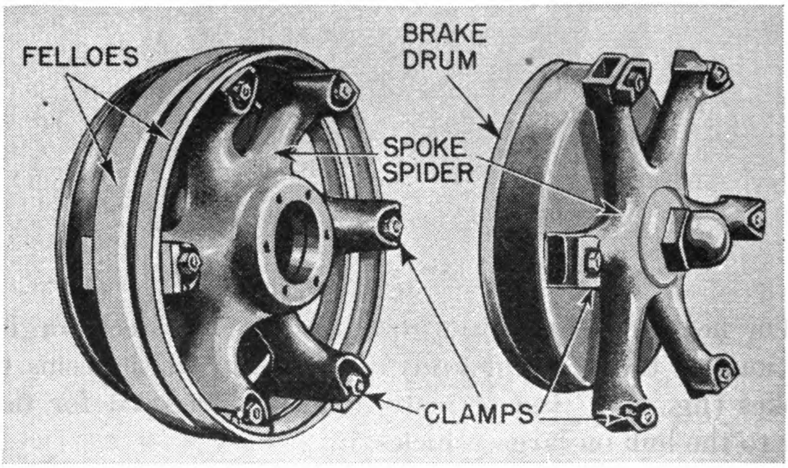

FIGURE 48.—Truck spoke wheels.

54. Dual wheels.—*a.* The use of dual rear wheels on heavier vehicles has made possible the use of small tires, interchangeable with those on the front wheels, without exceeding the safe load limit of the tires. The continued increase in gross loads on trucks, combined with legislation in many States limiting the maximum load per wheel as a protection for pavements, has lead to their wide use. A sep-

arate stamped disk is used for each wheel for dual disk wheels, whereas a single cast spoke spider is usually used for dual cast wheels.

b. Both disks of dual disk wheels are usually fastened together by two nuts on each hub bolt, one for each wheel (fig. 49). Either single or dual wheels can then be securely mounted on the same hub. The inner nut must be tightened first to hold the inner wheel disk to the hub. An outer nut, which threads onto the inner nut, is used to fasten the outer wheel disk. Left-hand threads are used on both inner and outer nuts for the hubs on the left wheels and right-hand threads for those on the right wheels.

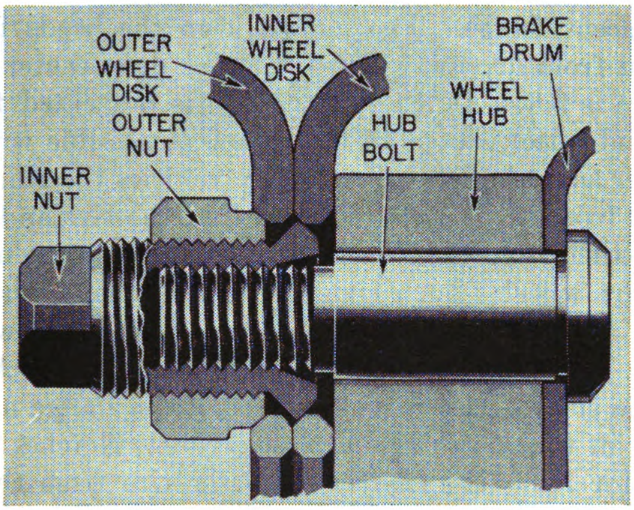

FIGURE 49.—Dual disk wheel mounting.

c. Two rims may be mounted on a single spoke spider by the method shown in figure 50. A spacer is inserted between the rims to maintain the proper distance between the dual wheel tires. The rims are fitted over the spokes and held in place by clamps that are fastened to the end of each spoke.

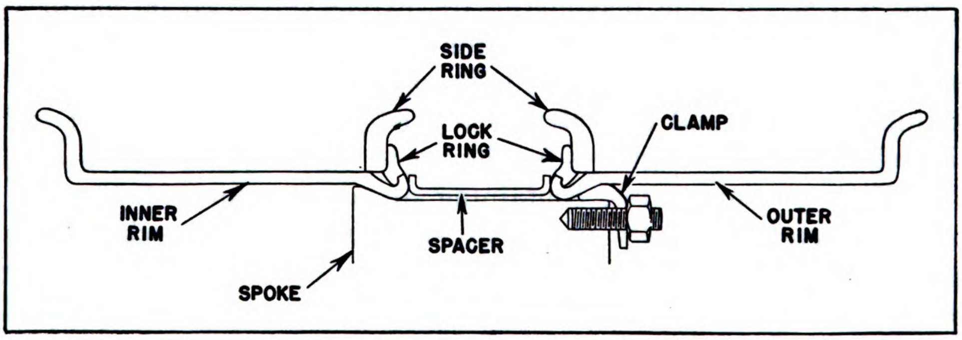

FIGURE 50.—Dual spoke wheel mounting.

55. Rims.—*a.* The wheel rim in all modern passenger cars is of the drop center type (figs. 45 and 46). The center portion of the rim is much smaller in diameter than the two outer edges which are flanged and provide seats for the tire beads. This construction makes it possible to install a pneumatic tire on a solid rim; for when both beads on one side of the tire are placed in the channel formed by the drop center, the beads on the other side may be slipped over the flanges onto the rim. When the tire is inflated the beads are forced against the flanges which hold the tire in place.

b. A recent innovation is the safety drop center rim in which a small hump is formed into the rim on each side of the drop center. Each bead of the tire then fits snugly between one of these humps and the adjacent flange. The humps keep the beads in place and prevent them from dropping down into the drop center section even when the tire is flat. As a result the tire is prevented from coming off the rim and better control of the vehicle is possible with a flat tire.

c. In larger size wheels used on heavy vehicles the rims are usually demountable from the wheel spider, so that the tire and rim may be removed together from the wheel. This eliminates the necessity of a complete spare wheel. Such rims are usually made with a flat base section (fig. 51) although they are sometimes made with a slight drop in the center (called semidrop center rims). As shown in figure 51, one side of the rim usually carries a flange and the other side a gutter in which is mounted a side ring. Notches are provided in the ring for removing the ring and the tire from the rim. The side ring is sometimes held in place against the tire by a lock ring (fig. 50) that is split to enable easy removal of the tire. A split side ring is often used, the split ends being butted together to form a smooth joint when locked in position against the tire.

d. Formerly, various types of demountable split rims were used but they have been replaced by drop center rims on light vehicles and demountable continuous rims on heavy vehicles.

56. Tires.—*a.* The pneumatic tire, extensively used on motor vehicles, provides a cushion of air for a vehicle to ride on. The tire consists of two parts: an inner tube to retain the air under pressure within the tire; and an outer casing to provide a surface of sufficient elasticity and toughness for the tire to ride on.

b. High pressure tires, containing an air pressure of 40 to 100 pounds, were extensively used, but are now used only when riding qualities are not important. Balloon tires, which are designed to carry the load with a comparatively low air pressure, are now widely

used. They are larger in width, smaller in diameter, and usually have thinner side walls than high pressure tires. Balloon tires for passenger cars contain 15 to 40 pounds of air pressure and for heavier vehicles 35 to 90 pounds.

c. A vehicle equipped with balloon tires will have a more comfortable ride because it provides a soft air cushion. Traction is better with balloon tires as there is a larger area in contact with the road surface. The braking effect, too, may be more pronounced.

57. Tubes.—*a.* The inner tube, also known as the air container, is made from rubber molded in tubular shape and formed into a ring with the ends vulcanized together. The tubular section is made

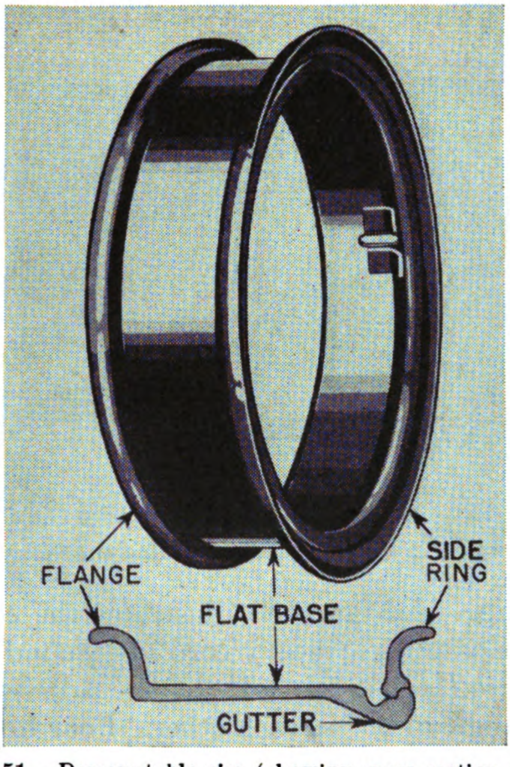

FIGURE 51.—Demountable rim (showing cross section of rim).

somewhat smaller than the inside of the tire casing and when inflated it stretches from 20 to 30 percent to fit against the casing. Air slowly seeps through an inflated tube and over a period of time will decrease the air pressure. Tire pressures should be checked frequently because of this leakage.

b. A tire valve is molded onto the inner tube (fig. 52) to allow the tire to be inflated and retain the pressure in the tire tube. A valve stem, which may be straight or bent, extends through the rim and is

covered by a valve cap to keep dirt and other foreign matter out of the valve.

c. When the tube is punctured, air will leak out and the tire will go flat. Tire patches made of rubber and applied with rubber cement or vulcanized by heat are used to seal a puncture so that the tube can still be used.

d. "Puncture proof" tubes have been developed. They are useful in military and other activities when a flat tire would be a vital hindrance to some operation. The tubes of these tires contain a special rubber compound that seals the puncture from the inside. The use of puncture proof tubes under ordinary driving conditions is not recommended because the sealing rubber unbalances and overheats the tire.

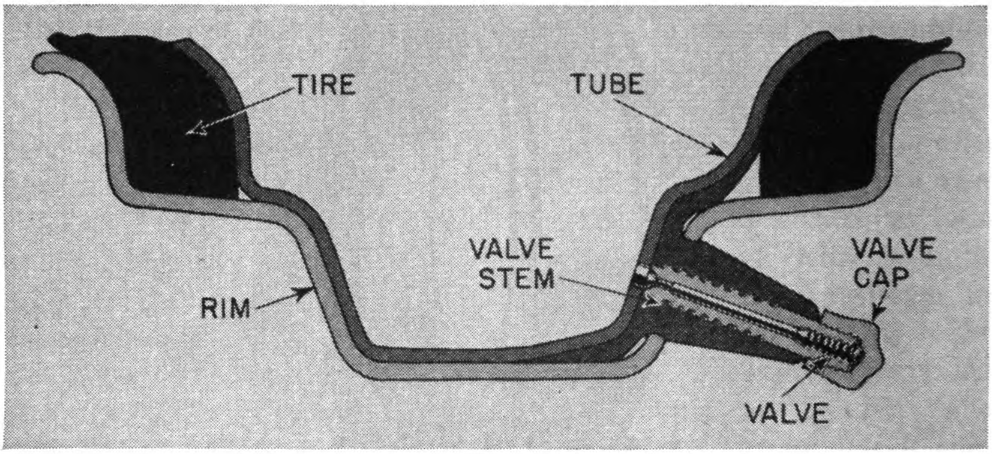

FIGURE 52.—Section of tire showing tire valve.

58. Tire casing.—*a.* Figure 53 illustrates the construction of a tire casing: layers or plies of heavy cord are wound around circular braids of piano wire (beads) into a U-shape. Adjacent layers of cord are wound at an angle of 90° to each other. Four to sixteen plies are used, depending upon the size of the tire and the service to which it will be put. A thin layer of rubber gum is placed between all layers. The cord used in the construction of these tires is often rubber-dipped to give it strength, flexibility, and to reduce internal friction. Over this carcass is built a cushion of compounded rubber containing layers of cord called breaker strips. Outside of this cushion is the tread which comes in contact with the road and, consequently, takes the wear. There is also a thin layer of rubber over the sides. This whole structure is then vulcanized or baked into a solid unit. Great care and considerable experience are needed in this operation as too much

vulcanizing will make the rubber hard and brittle, while too little vulcanizing will leave it too soft to resist wear.

b. Many tread designs are used by manufacturers to give the necessary traction and to reduce the tendency to skid. The design used depends upon the type of service to which the tire will be subjected. Various antiskid devices are fitted over the tire to reduce skidding and increase traction under bad driving conditions. Special traction devices are also used over the tire to increase the traction on difficult terrain.

59. Proper use and care of tires.—*a.* One of the most important problems in motor maintenance is that of giving tires proper care and attention. This is important because good tires are essential for safe

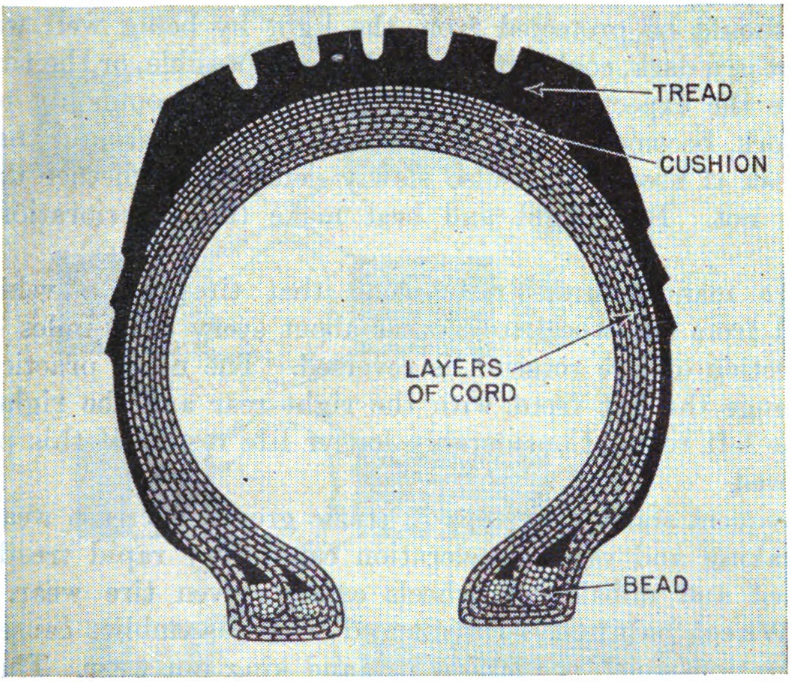

FIGURE 53.—Cross section of tire casing.

driving. Tire troubles come mainly through neglect and can usually be avoided by taking a little trouble.

b. As the tire rolls on the road it tends to flatten out or bulge under load and to resume its shape as it turns and the load is released. This flexing of the tire heats it. If the tire is operated at less than the correct air pressure, the flexing and heating become excessive and the tire quickly wears out.

c. Proper inflation and loading of tires are very important factors in tire wear. The tread will wear unevenly and the life of the tire

will be materially shortened if the manufacturers' recommendations are not followed (fig. 54).

d. Increased speed reduces the mileage obtainable from tires. This has been proved by numerous tests. For instance, one series of tests proved that at the same temperature and on the same roads a tire driven continuously at 35 miles per hour has twice the life of a similar tire driven at 50 miles per hour. High speed driving affects tires on all four wheels but is especially severe on the driving tires.

e. Experiments have shown that excessive heat causes rapid tread wear. For example, an increase from 70° to 90° will nearly double the rate of wear. This is one reason why tires wear so much faster in summer. Tests also have shown that dry roads are far more abrasive than wet roads and therefore decrease tire life. Extra tire casing should be protected from the light by being well wrapped and kept in a dark, cool, dry place whenever possible, or the tires will not give the expected mileage. Rubber bands, commonly used in office work, become so old and brittle from lying around that they will break if used. Tires also slowly deteriorate whether they are used or not. Both light and heat make this deterioration more rapid.

f. Tire manufacturers recommend that tires on a vehicle be changed from one wheel to another about every 5,000 miles so that the direction of tire rotation is reversed. The usual practice is to interchange the left front with the right rear and the right front with the left rear. Considerably longer life results if this practice is followed.

g. Frequent starts and stops in traffic greatly increase wear. Severe braking and rapid acceleration cause very rapid tread wear. Misalined and unbalanced wheels cause uneven tire wear.

60. Wheel balance.—Unbalanced wheel assemblies cause excessive vibration which accelerates tire and king pin wear. The steering play thus developed often results in wheel shake (shimmy), and front tire tread wear becomes very rapid. Perfect balance of the wheel assembly is desirable. If care is exercised when the tube is inserted in the casing, the wheel balance will be satisfactory. The tube is unbalanced by the valve. To overcome this, some marking is usually placed on the tire wall to indicate the light side of the tire casing. If the valve stem is placed next to this mark when assembling the tire, the best balance will be obtained. If satisfactory balance cannot be obtained, the wheel assembly must be removed from the axle. To obtain perfect static balance, a close-fitting shaft is inserted through the hub and placed on a carefully

leveled knife edge support. The wheel is permitted to roll until it comes to rest (heavy side down). A balancing lug may then be secured to the wheel rim flange. Perfect balance may be attained by repeating this procedure until the assembly gives no indication of rolling on the knife edges regardless of its position.

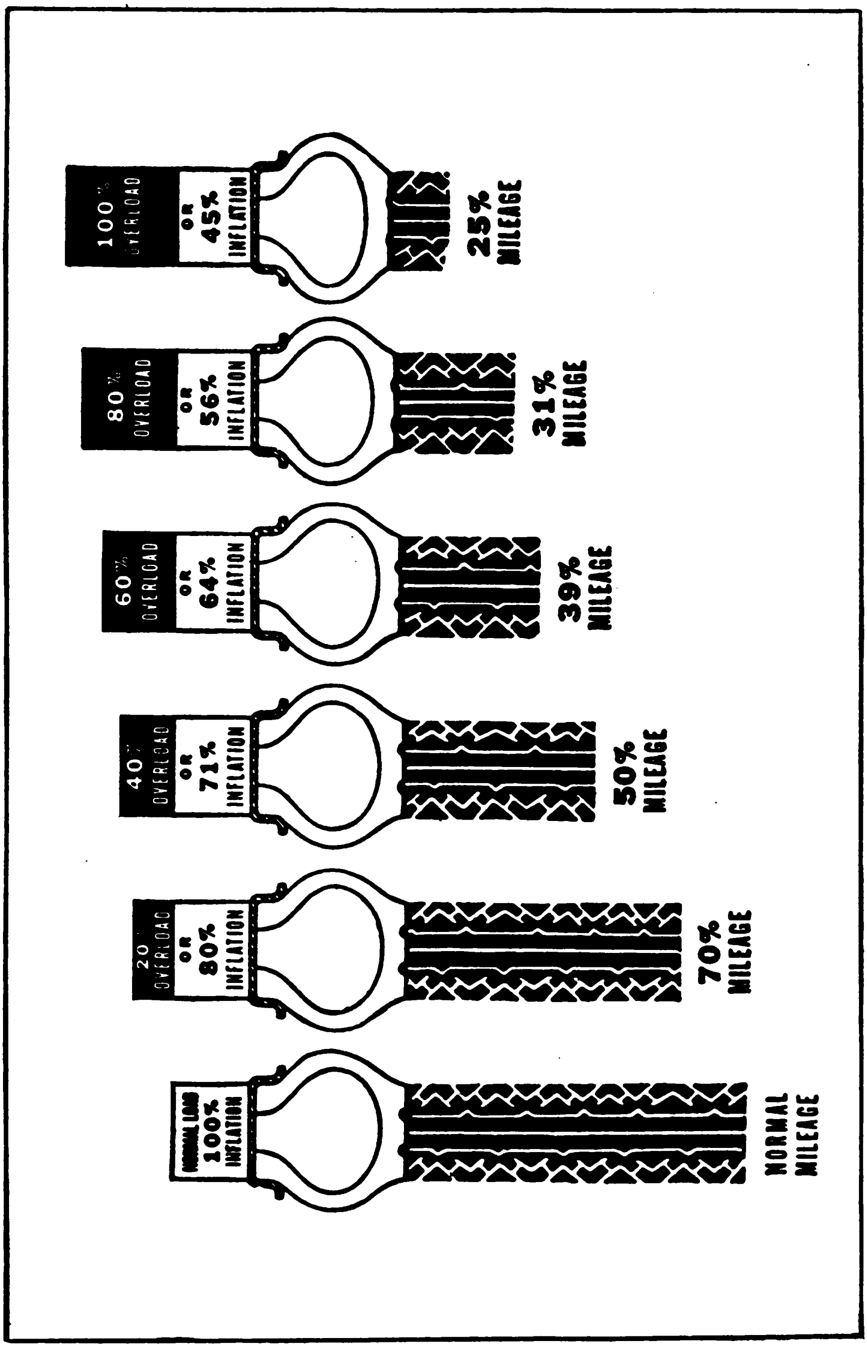

FIGURE 54.—Effect of overloading and underinflation of tires.

SECTION VIII

BODIES

61. Passenger car bodies.—*a.* Much attention has been given to passenger car body design in recent years and as a result many changes have been introduced. The general appearance of the bodies is changed by the manufacturers every year or two. The recent trend has been to design the body so that wind resistance is reduced to a minimum. Such designing, known as "streamlining," has no effect at low speeds but materially reduces the resistance to vehicle motion at high speeds.

b. The majority of bodies were open in early motor vehicles. With the development of safety glass and good steel welding, closed bodies have become widely used. A few convertible bodies provided with adjustable windows and a top that may be folded back are being used.

c. Body types for passenger cars depend on the number of passengers to be accommodated. Various names are given the different body types by the manufacturers. The terminology sometimes differs although the differences in construction are not very marked. The principal passenger car body types are—

(1) *Roadster.*—An open body with one cross seat and a rear compartment, sometimes containing a rumble seat. A top that folds back and removable side curtains are provided for protection from the weather.

(2) *Coupe.*—A closed body with one cross seat and a rear compartment, sometimes containing a rumble seat.

(3) *Touring car or phaeton.*—An open body with two cross seats. A top that folds back and removable side curtains are provided for protection from the weather (fig. 55).

(4) *Sedan.*—A closed body with two cross seats. The front seats of a 2-door sedan, usually called a coach, are made folding to afford entrance to the rear seat.

d. The body of a motor vehicle, especially of a passenger car, should be comfortable and convenient for driver and passenger, give ample protection from the weather, and insure reasonable safety in case of accident. In addition, the body should be free from distracting noises when the vehicle is in operation. These requirements

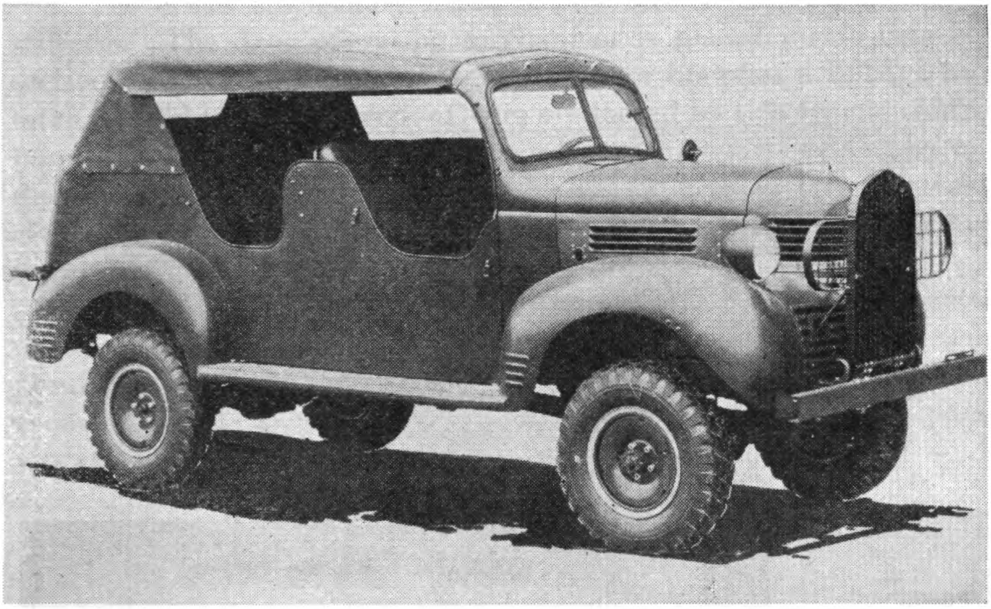

FIGURE 55.—Command body on ½-ton 4 x 4 chassis.

are best met with an all steel body construction. Composite bodies made of wood and steel were used until recently.

62. Steel body.—*a.* The all steel body used on modern passenger cars provides a light and rigid structure. A steel sedan body (fig. 56) is made up of a large number of sections welded into a unit.

b. The steel sheets from which the various sections of the body are made, some 25 in number, are cut to size and pressed into shape by large presses. These sheets are then assembled in jigs and spot-welded together with reinforcing members into several main subassemblies: the back and quarter panel assembly, consisting of the back and two side panels and the rear wheel housing; the shroud assembly, containing the cowl, dash, and instrument panels; the body bed, containing the various floor pans; the pillar assemblies, containing the door posts, body sills, and roof bows; and the doors. These various subassemblies are then placed in a large welding machine which permanently welds the seams together along their entire length. In some cases the posts and certain other parts are welded in with the oxyacetylene flame. Figure 57 shows the completed framework construction on an all steel body.

c. A variety of special tools and equipment are used to file down the welds and smooth the outer panels. When the operation is complete, the surface is so smooth that it is impossible to tell where the welds were made.

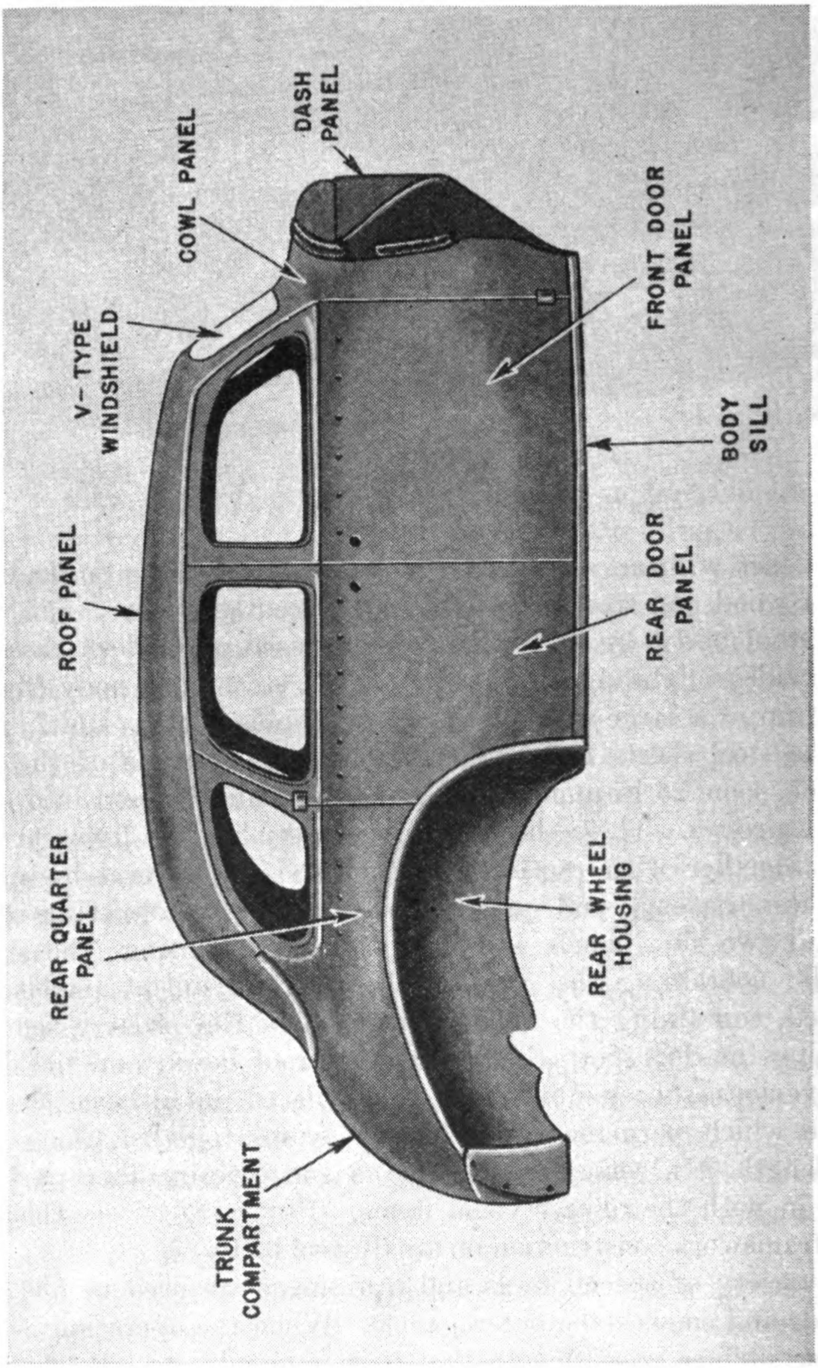

FIGURE 56.—Passenger car (sedan) steel body.

d. The doors are usually made with a box section which insures stiffness. The door operating mechanism is placed inside this box section. A handle on the inside of the door operates a linkage to a latch to hold the door closed. Doors are locked by this remote control handle up or by a separate button. A key lock is provided on one door. The doors are mounted on hinges (concealed on some vehicles), and checks and bumpers are provided to limit its swing and to prevent rubbing contact with the door pillars.

63. Finished body.—*a.* Insulating material is usually cemented to all of the various body panels. This materially reduces the temperature inside the vehicle during the summer, especially the heat from the engine, and decreases the rumbling noise caused by panel vibration.

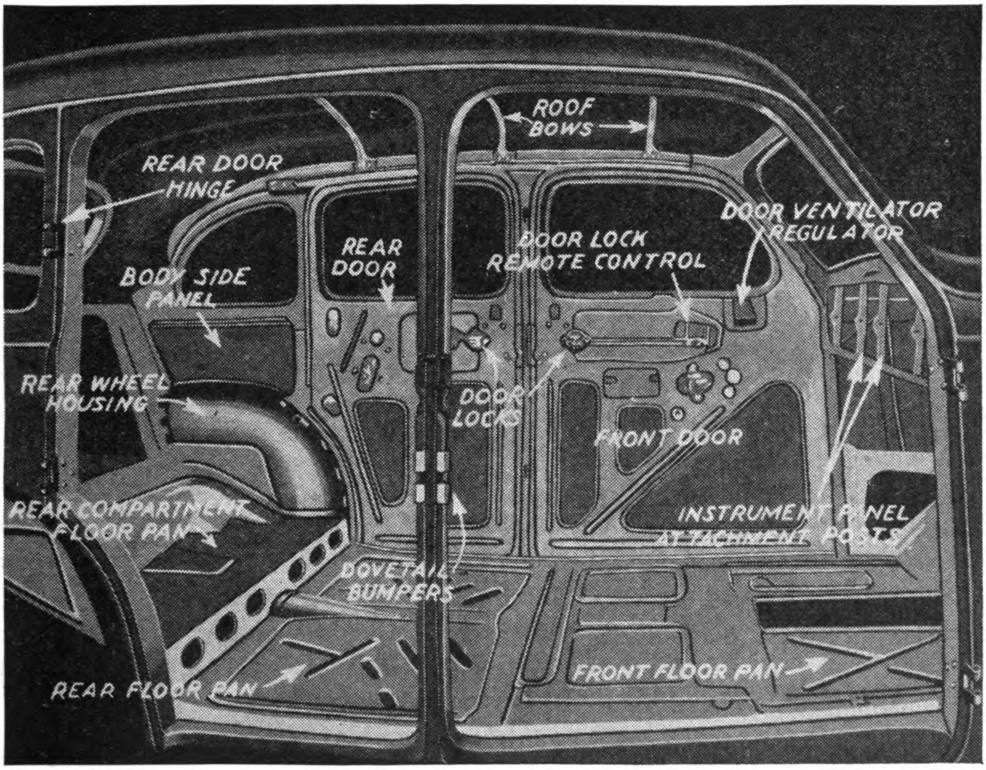

FIGURE 57.—All steel body construction.

b. The body is mounted on the chassis by bolts, and rubber cushions or cork or fabric body shims are often used to eliminate squeaking at the body mountings and to reduce the engine and road vibrations transmitted to the body (fig. 58). Fenders and engine hood are attached to the body separately. Running boards, to which are vulcanized rubber step mats, are mounted on the chassis independently.

The cowl panel is usually provided with a ventilator to admit air to the body. The ventilator closes into a recess containing a drain gutter and a rubber tube to prevent water getting into the body.

c. Windshields, which usually do not open, may be in one piece, or of the V-type consisting of two panes set at an angle, with a rubber molding between the plates. Safety (shatterproof) glass is required in the windshield and all the windows by state laws. Ventilation is provided in some types by divided window panes, which may be moved independently of the remainder of the window. Window regulators on door windows are usually provided to move the windows up or down.

d. Practically all models are equipped with an enclosed trunk compartment at the rear, which usually carries the spare wheel and tire.

e. The seat cushions are mounted on the floor pans. The back cush-

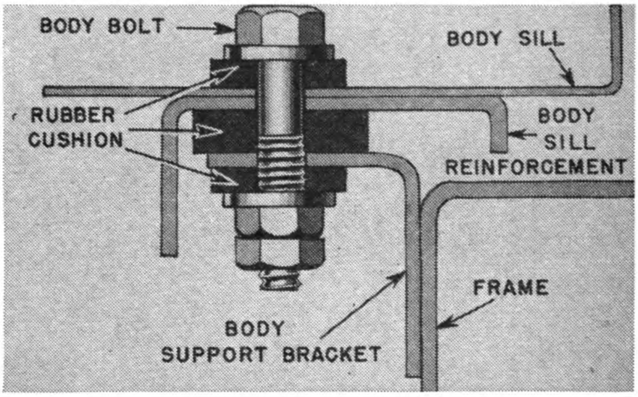

FIGURE 58.—Rubber body mounting.

ion for the back seat is usually attached to the body. The front, or driver's, seat cushion and its back cushion are mounted together on a framework that is mounted on rails so that its position can be adjusted backward or forward to suit the driver. Seat and back cushions (fig. 59) are made of light coil springs tied together in position. A hair or rubber pad is placed over these springs for comfort. Upholstery cloth or other material is used to cover the seat and is fastened over all the body interior to cover up the unsightly body construction.

f. Rubber or mat material is placed over the floor pans. Body hardware is provided for all window and windshield regulators, door handles, and various accessories.

64. Operator's compartment.—*a.* The operator's compartment is in the front of the passenger car body. On trucks a separate cab is usually provided which is of steel construction and made somewhat like the passenger car steel body. To reduce the over-all length of

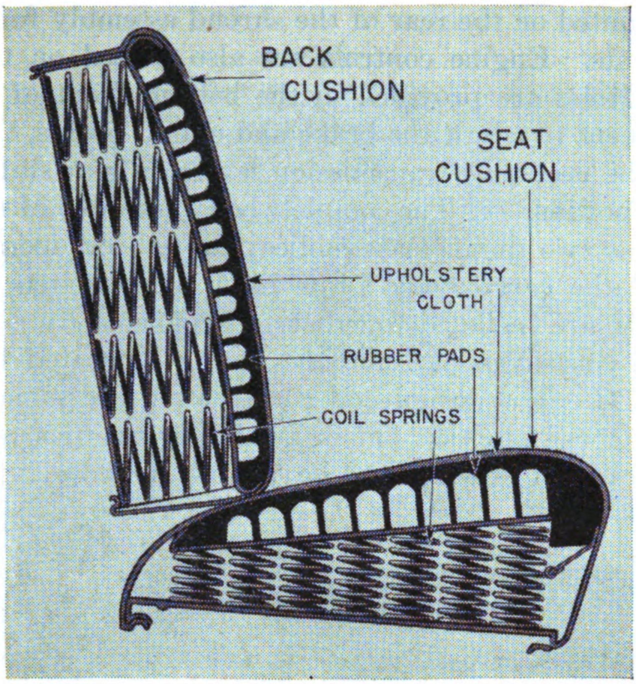

FIGURE 59.—Seat construction.

a truck, the cab is sometimes placed directly over the engine. Open cabs are used on a few trucks.

b. All of the vehicle controls and indicating instruments are brought up to the interior of the operator's compartment (fig. 60).

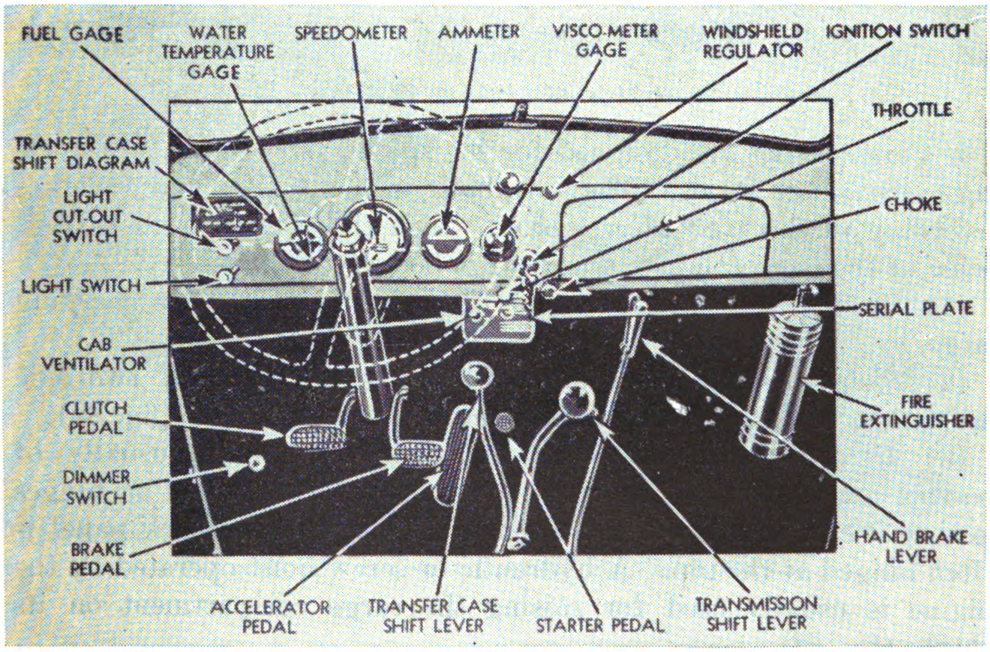

FIGURE 60.—Operator's compartment.

A panel is mounted on the rear of the shroud assembly for the necessary instruments. Engine controls are also placed on this instrument panel. Holes are provided in the bottom front of the operator's compartment to admit the brake and clutch pedals, the steering column, and the necessary transmission levers or gear shifts.

65. Truck bodies.—*a.* The complete body assembly of most trucks is considered as two distinct assemblies: the cab or operator's compartment and the cargo body. For light delivery trucks the cab and cargo body are included together in a panel body construction, the operator's compartment sometimes being separated by a panel or wall (fig. 61). The design and construction are somewhat similar to passenger car practice, but in the larger size trucks, parts are heavier and designed to withstand heavy and sustained stresses.

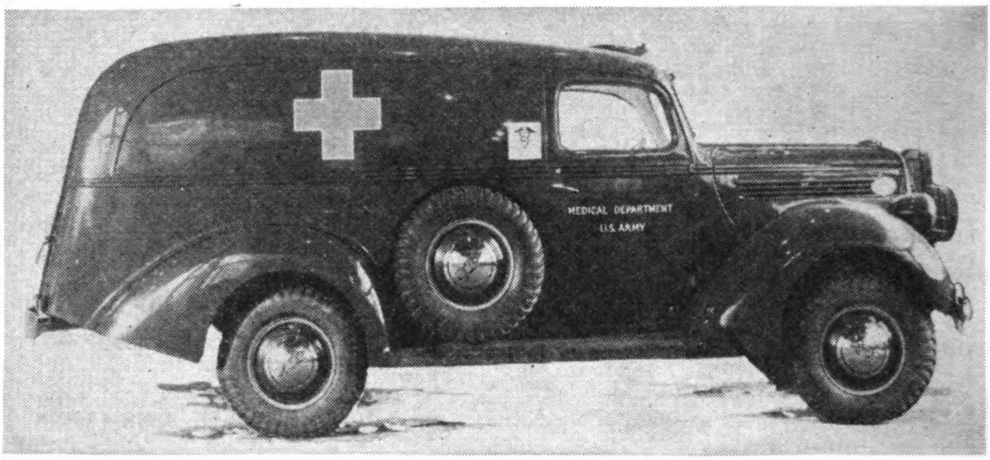

FIGURE 61.—Panel body on ambulance.

b. Cargo bodies are designed for the special purpose of transporting materials or goods. They are built in many sizes and varieties according to the type of service to which the vehicle is to be put. Some of the more common truck cargo body types are—

(1) *Platform.*—Consists merely of a flat platform for carrying cargo.

(2) *Pick-up.*—A shallow boxlike construction, built of two side panels and a hinged back panel that can be swung down (fig. 62).

(3) *Dump.*—Built somewhat like pick-up although usually of heavier construction. The cargo compartment is mounted on hinges so that it can be raised for emptying the cargo. The back panel is often hinged at the top. A hydraulic or screw hoist operated by the engine is usually used for raising the cargo compartment on its hinges (fig. 63).

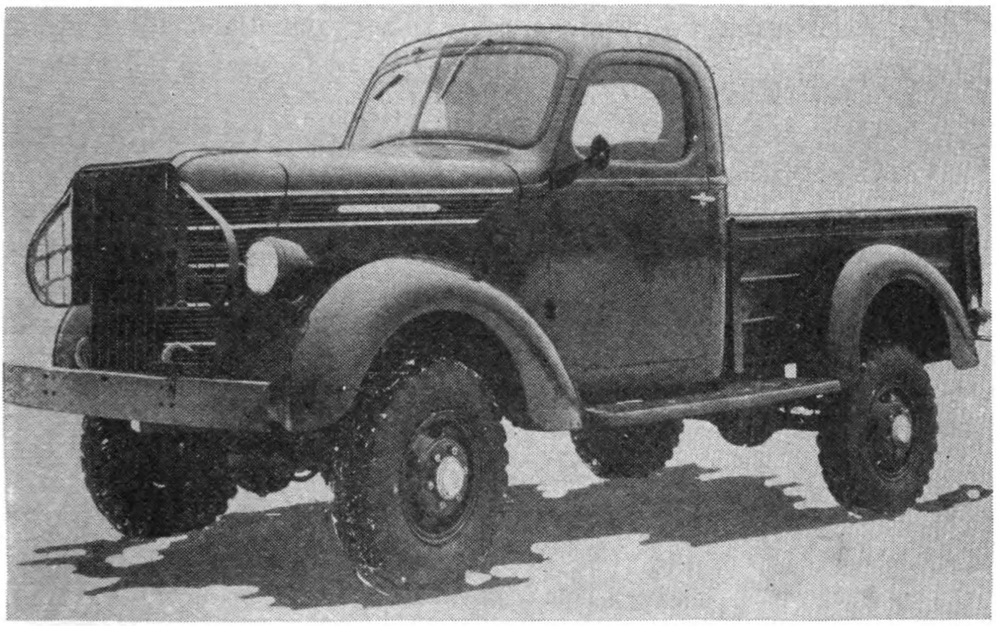

FIGURE 62.—Pick-up body (closed cab) on ½-ton truck.

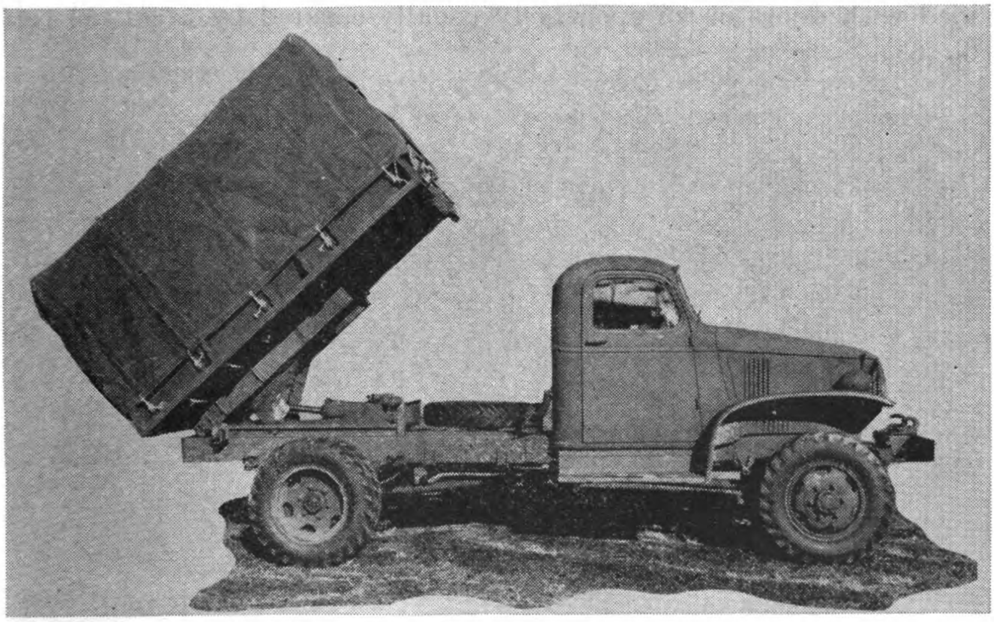

FIGURE 63.—Dump body (closed cab) on 1½-ton truck.

(4) *Stake.*—Consists of a flat platform or a shallow box construction with wood or steel stakes fastened along the edge to retain the cargo (fig. 64).

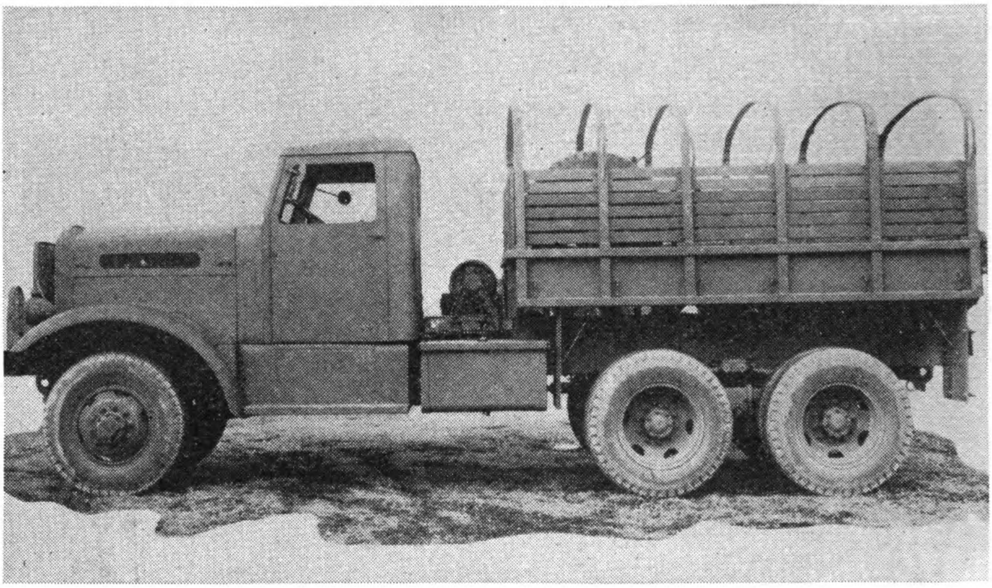

FIGURE 64.—Stake body (closed cab) on 6-ton truck.

(5) *Cargo.*—Usually of heavy construction with a closed body provided with doors or an open body usually covered by a canvas top (fig. 65).

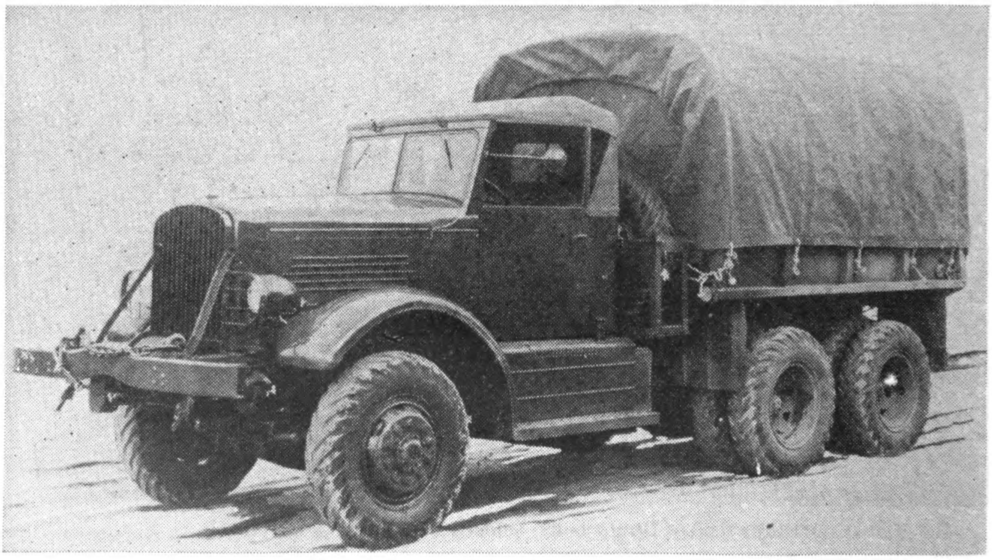

FIGURE 65.—Cargo body (open cab) on 4-ton truck.

(6) *Special.*—There are numerous specialized truck bodies for vehicles (such as tank trucks, fire trucks, prime movers, etc.) designed for particular duties. An example of a fire truck body is illustrated in figure 66.

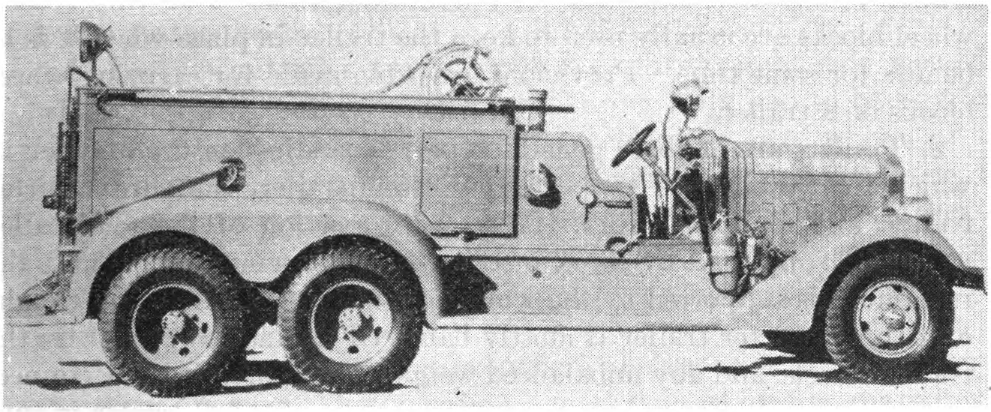

FIGURE 66.—Specialized body on fire truck.

SECTION IX

TRAILERS

66. General.—*a.* A motor vehicle can pull a heavier load than it can safely carry. This fact is put to use in motor transportation by using trailers. A trailer is a cargo vehicle with no motive power of its own, towed by a motor vehicle. Motor vehicles specially designed for towing trailers are known as tractors.

b. Considerable time must be spent in loading and unloading certain types of cargoes. In such cases trailers are useful because they can be left at the loading and unloading points while the tractor tows other loads.

c. Trailer spring suspension is the same as that employed on motor vehicles. Auxiliary springs are often used. Radius rods are usually used to maintain axle alinement and to transmit braking and pulling action between the trailer axle and frame. The wheels are usually slightly cambered.

d. Air, vacuum, or electric braking systems are used with trailers. The trailer braking system is coupled to that of the towing vehicle by

a flexible hose and detachable couplings or cables. The trailer braking system is usually designed so that the brakes are applied and keep the trailer in place when these couplings are disconnected. However, when the trailer is detached from the towing vehicle, the trailer brakes will hold for only a limited time. For this reason wheel blocks are usually used to keep the trailer in place when it is to be idle for some time. Provisions are often made for carrying wheel blocks on a trailer.

e. Trailers are of three general types, depending on the manner in which their weight is supported: the semitrailer, the three-quarter trailer, and the full trailer. A large proportion of the semitrailer weight is supported by its connection to the towing vehicle and the remainder is supported by the wheels of the semitrailer. The weight of a three-quarter trailer is mostly balanced on and supported by the trailer wheels, and any unbalanced weight is supported by the connection to the towing vehicle. The entire weight of a full trailer is supported by the trailer wheels.

f. Trailers are made in many sizes and equipped with various body styles depending upon the service for which they are intended. The connections between towing vehicles and trailers differ according to the type of trailer involved. Two main types are used: the fifth wheel (semitrailers), and the pintle hook connection (three-quarter and full trailers).

67. Semitrailers.—*a.* A typical semitrailer chassis (fig. 67) consists mainly of a frame, spring suspension, axle, fifth wheel connection,

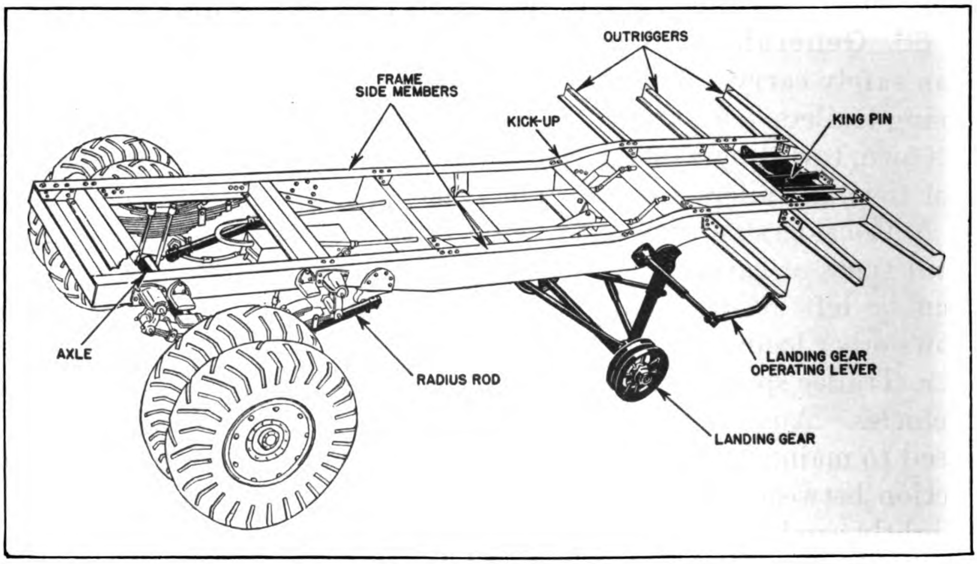

FIGURE 67.—Semitrailer chassis.

and a landing gear. It resembles the conventional truck chassis in that its frame is made of two pressed-steel side members with several cross members, laminated leaf spring suspension, and wheels and tires that are interchangeable with the tractor used for hauling the trailer. Figure 68 illustrates a trailer chassis with tandem axles for carrying heavy trailer loads.

b. Early semitrailer frames were built of straight side members, which meant that the rear of a level trailer body had to be at a considerable height above the ground to clear the rear wheels of the tractor. Such a high frame is objectionable because it heightens the center of gravity, making it easier to overturn the trailer. A kick-up in the semitrailer frame (fig. 67) permits a lower center of gravity without reducing the necessary clearance space above the rear wheels of the motor vehicle.

c. Cross members are located where the greatest strains occur to the trailer frame. They may be tubular, channel, or box shaped, with gusset plates riveted or welded to the side members to make a rigid, strong frame.

d. Another type of semitrailer with a variable wheelbase is the "pole" trailer used for transporting long or irregularly shaped goods, such as poles, pipes, or structural members. In this case the "pole" or "boom" forms the trailer frame. The pole is attached to a turntable mounted on the tractor in much the same manner as a fifth wheel. The trailer axle unit is attached by adjustable clamps to the other end of the pole.

e. A tractor used to haul a semitrailer must be especially designed. Its wheelbase is shorter than that of a standard truck, and the engine and transmission units are designed to produce the necessary power for pulling a loaded semitrailer. Tractors may be of the cab over engine (fig. 69) or conventional truck design with either single or dual rear axles. The flexible hose connecting the brake system of the tractor to the trailer is clearly shown at the rear of the tractor cab.

68. Landing gear.—*a.* The landing gear (fig. 70) is a retractable support under the front end of a semitrailer to hold it up when it is uncoupled from the tractor. The two leg members of the landing gear are usually attached to the under side of the trailer chassis by pivot pins. These leg members are connected together by cross braces to resist any side strains. Two small steel wheels mounted on the ends of these leg members facilitate moving the trailer about when it is uncoupled from the tractor. Bracing members connect the lower end of the leg members to a movable bracket containing a nut which rides

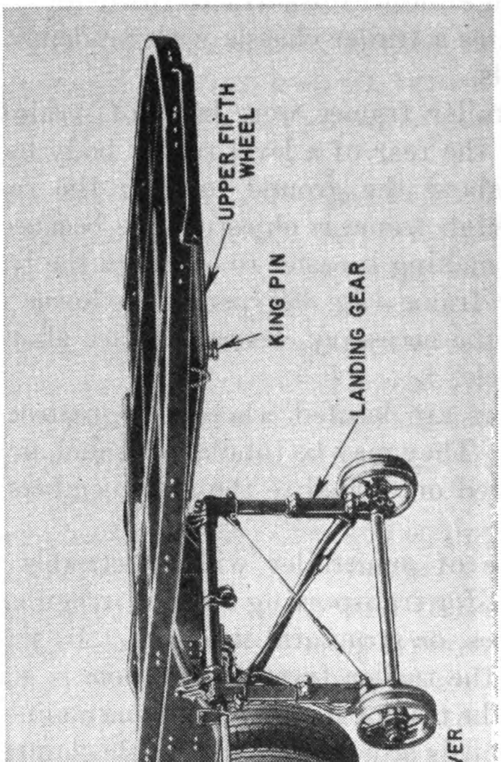

FIGURE 68.—Semitrailer chassis with tandem axles.

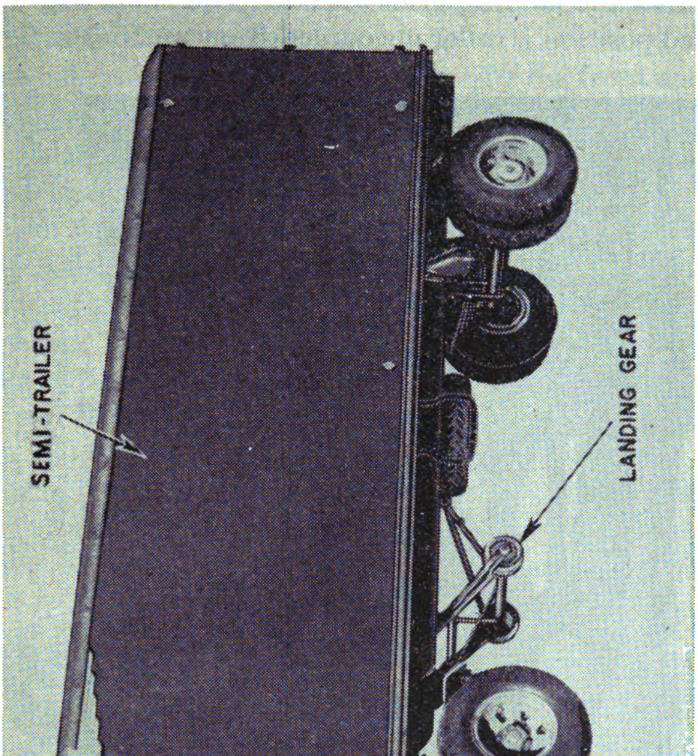

FIGURE 69.—Tractor semitrailer combination.

on a worm shaft located lengthwise between the side members of the trailer frame. Rotation of the worm shaft moves the bracket forward or backward (depending on the direction of rotation) and consequently lowers or raises the landing gear wheels. The landing gear is shown in its lowered position (trailer uncoupled from tractor) in figure 70.

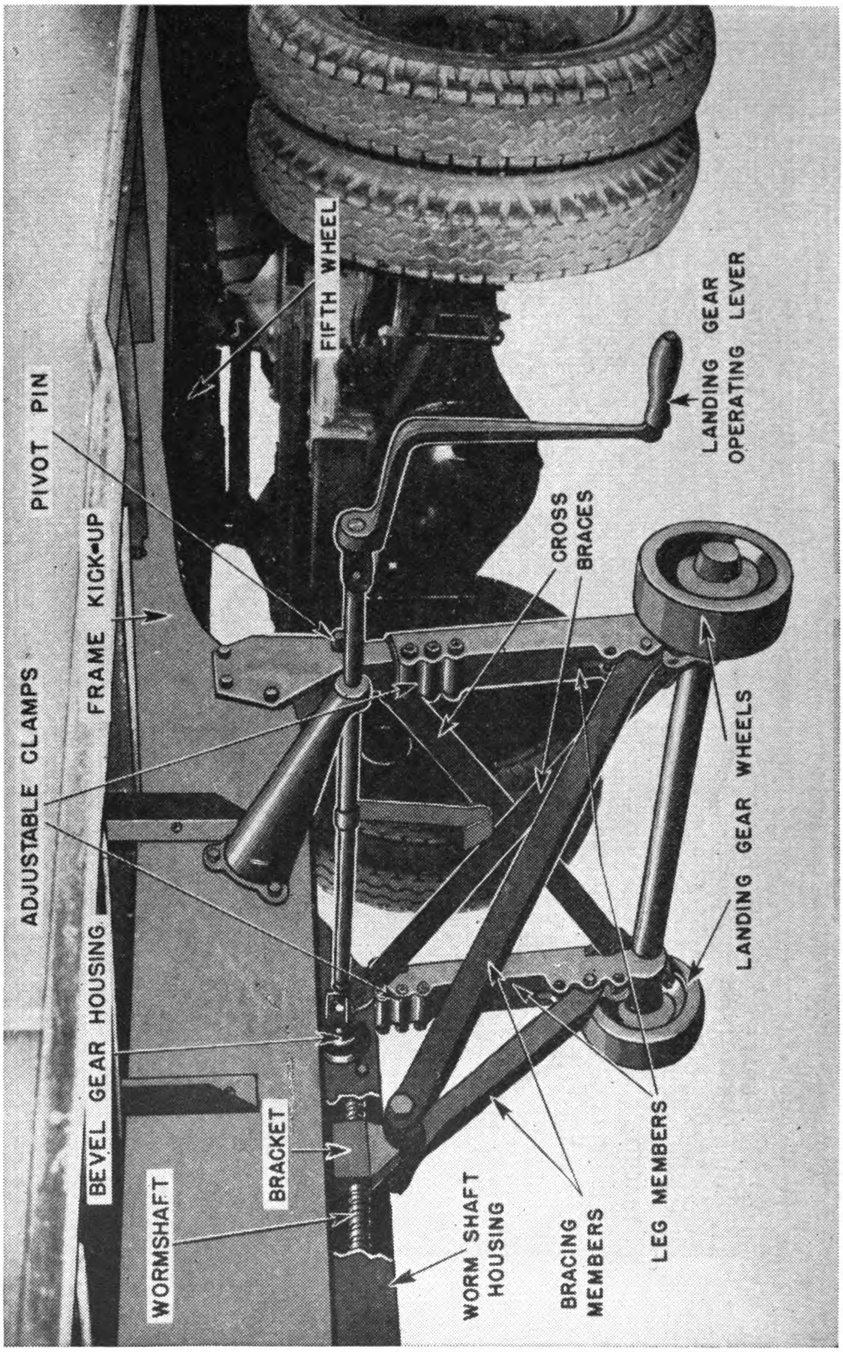

FIGURE 70.—Landing gear of a semitrailer.

b. The worm shaft is supported by bearings in a housing mounted on the under side of the trailer chassis. It is rotated by means of a set of bevel gears at the forward end of the housing. These gears are turned by a hand-operated lever at the end of a shaft which extends out to the side of the trailer.

c. The height which the landing gear lifts the front end of the trailer above the ground can be varied by adjustable clamps at the top of the two leg members. This adjustment is necessary if the trailer is to be used with tractors having different rear end heights.

d. When semitrailers are coupled and uncoupled, it is important that the landing gear be coordinated with the fifth wheel lock. If the landing gear is elevated before the fifth wheel connection is fully locked, the front end of the trailer will drop to the ground when the tractor is driven away, with the possibility of damaging both the load and the semitrailer. Before the semitrailer is uncoupled, the brake coupling should be disconnected so that the semitrailer brakes are applied to prevent it from moving. Automatic controls are sometimes used to coordinate the desired features. Auxiliary locking pins (fig. 71) strike against the lower fifth wheel

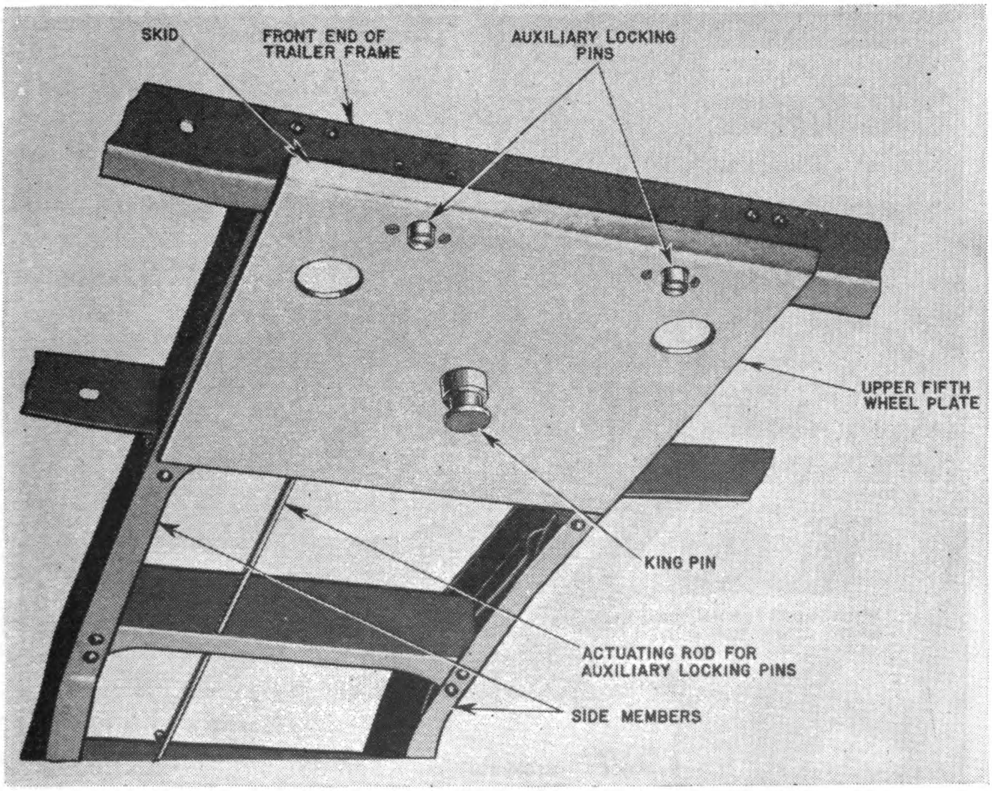

FIGURE 71.—Under side of semitrailer frame showing upper fifth wheel.

plate on the tractor and lock the fifth wheel connection, thereby preventing the trailer from being separated until the landing gear is fully lowered. These auxiliary locking pins are connected by an actuating rod in such a way that they cannot be raised to unlock the fifth wheel connection until the landing gear is fully lowered and the trailer brakes applied.

69. Fifth wheel.—*a.* The standard method of connecting the tractor to the semitrailer is by means of a fifth wheel. A heavy steel plate, known as the upper fifth wheel plate, is securely attached to the under side of the front end of the semitrailer frame (fig. 71). This plate serves as the bearing or front end support of the semitrailer when it is coupled to a tractor. The front edge of the plate is turned up approximately 45° to form a skid which slides on the lower fifth wheel plate (mounted on the tractor) when the semitrailer is being hitched to the tractor. In the center of the upper fifth wheel plate is a permanently attached king pin by which the tractor pulls the semitrailer.

b. The lower fifth wheel (fig. 72) contains the movable parts of the fifth wheel assembly and supports the semitrailer load thrust

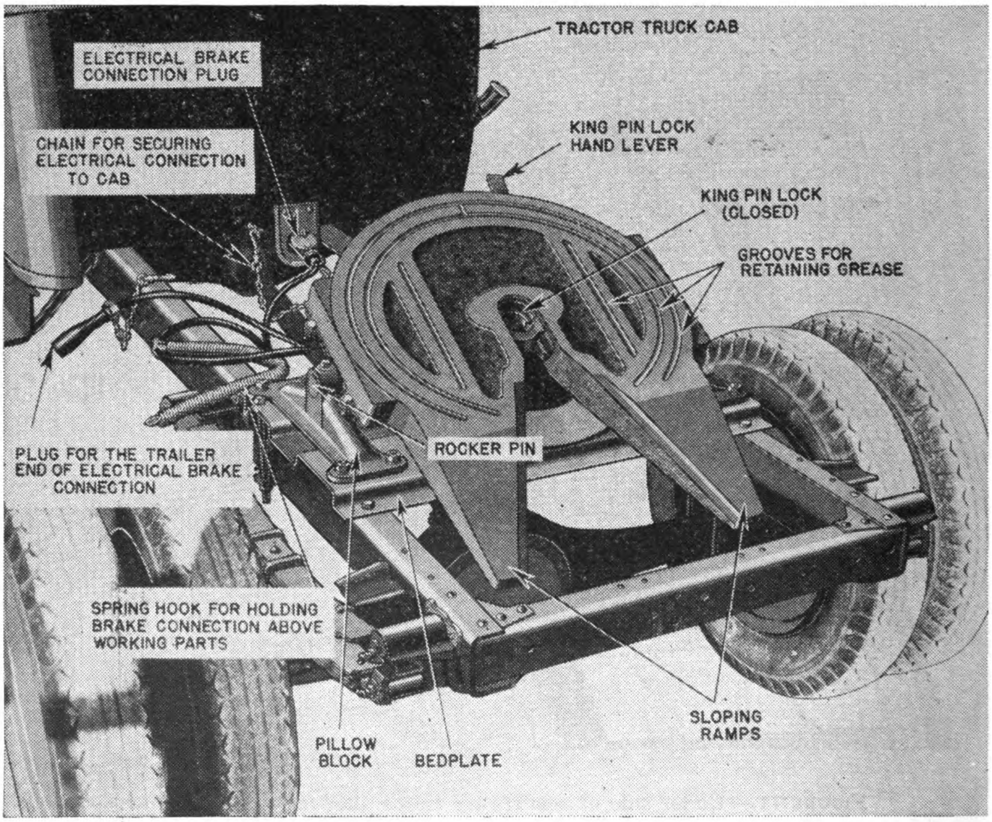

FIGURE 72.—Lower fifth wheel mounted on tractor (semiautomatic coupling).

on the tractor. The circular portion of the heavy cast steel plate is the bearing surface upon which the upper plate of the semitrailer rides. The circular grooves in the lower plate are grease retainers for lubricating the rubbing surfaces of the upper and lower plates. The sloping ramps aid in picking up the upper plate of the semitrailer. The wide open space between the ramps guides the king pin into place. The lower plate is pivoted on a rocker pin crosswise to the tractor, providing a free swinging movement between the semitrailer and tractor. The outer ends of the rocker pin are supported in pillow blocks bolted to a bedplate which is mounted on the frame of the tractor.

c. There are three types of fifth wheel couplings: permanent, semiautomatic, and automatic. In a permanent fifth wheel coupling the king pin is made part of the lower fifth wheel plate, and once locked in position the tractor is operated with the same semitrailer at all times. In semiautomatic and automatic fifth wheel couplings, the king pin is contained on the upper fifth wheel plate. The king pin is locked in position by a king pin lock which is a ring on the lower fifth wheel that clamps around the king pin. In the semiautomatic coupling, which is the most popular type, the king pin lock is operated by a hand lever that extends to the side of the lower fifth wheel (fig. 72). The automatic coupling is locked in a similar manner, except that it is controlled by the operator from the tractor cab.

70. Load distribution.—*a.* The fifth wheel should be located at a point on the tractor chassis that will best distribute the portion of the semitrailer load thrust on the tractor. The ideal load distribution for a tractor and semitrailer combination is illustrated in figure 73. The fifth wheel should be well ahead of the tractor rear axle to accomplish this.

b. Another important factor in the location of the fifth wheel is that of safety in hilly or mountainous country. When climbing hills the load thrust will act at a point back of the tractor rear wheels (fig. 74), if the fifth wheel is located directly over the rear wheels, and will tend to raise the front wheels of the tractor off the road. This will cause a dangerous loss of steering control, which is aggravated by each bump in the road. With the fifth wheel and consequently the load center located well ahead of the rear wheels, this hazard is avoided as the load thrust will always fall ahead of the driving axle.

c. Another danger from an incorrectly located fifth wheel is that due to the momentum of the trailer. The momentum of the trailer

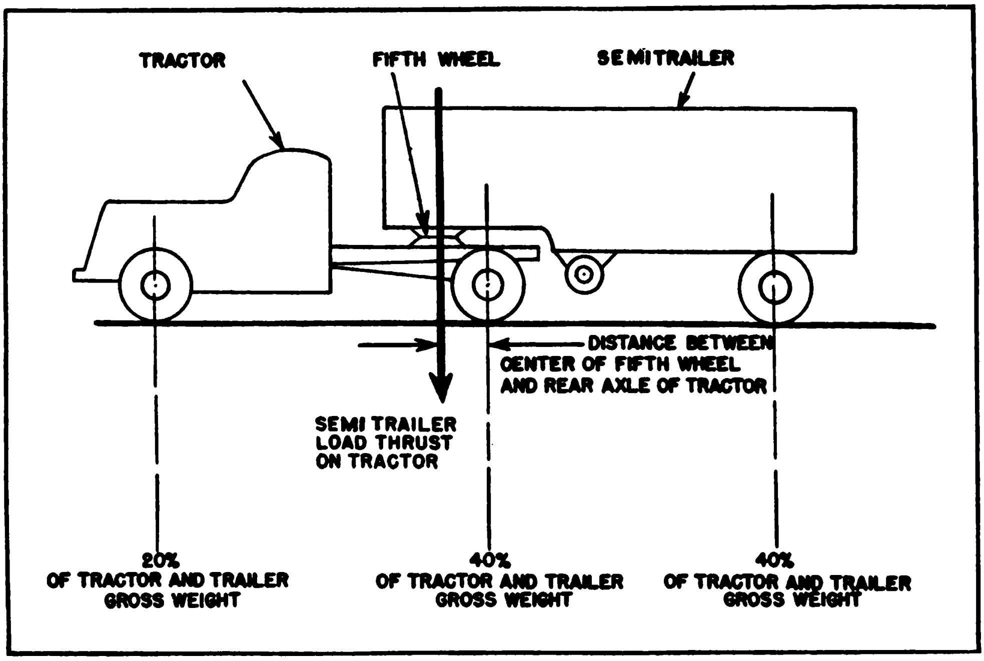

FIGURE 73.—Ideal load distribution for tractor and semitrailer combination.

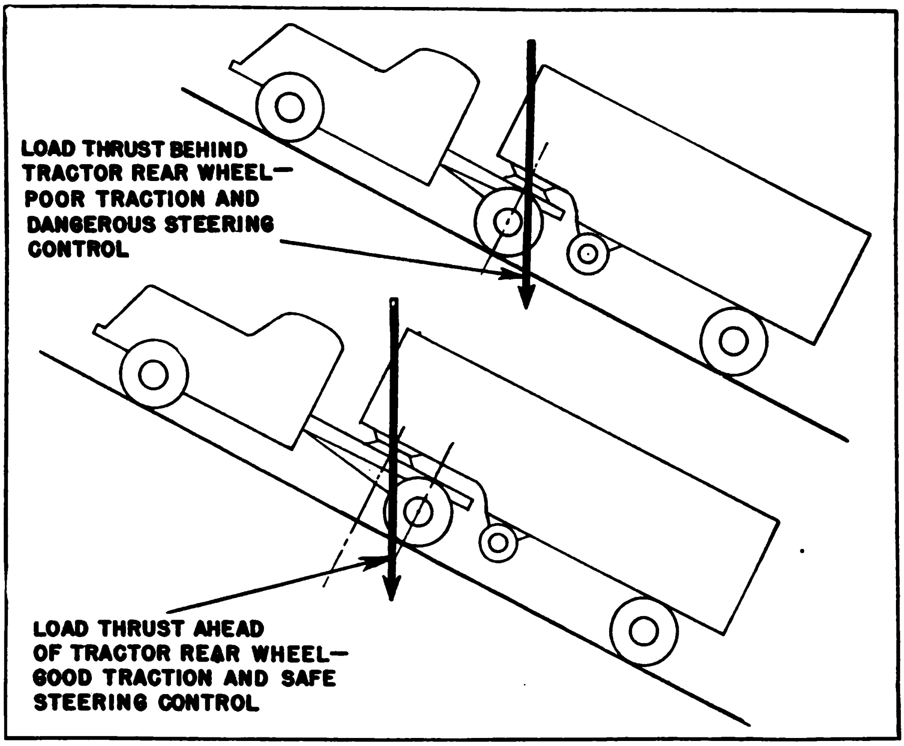

FIGURE 74.—Effect of fifth wheel location when climbing hills.

has a tendency to push the rear end of the tractor off the road when on a sharp turn (jackknifing), especially if the road is wet or covered with ice or snow. With the fifth wheel located well ahead of the tractor rear wheels, the load thrust is placed between the tractor axles and offers additional resistance to the momentum of the trailer when it tends to jackknife.

d. Clearance between the rear of the tractor cab and the front of the semitrailer body should always be at least 1 foot.

71. Three-quarter trailers.—*a.* Three-quarter (usually 2-wheel) trailers are used for light loads. The entire trailer load is practically balanced on the trailer suspension. Usually about 15 percent of the trailer load is thrust on the tractor connection. Three-quarter trailers are built in many sizes and fitted with various forms of bodies ranging from the general pick-up and tank (fuel and water) to the more elaborate house trailers used as hospital and recruiting vehicles. In some of the heavier types, tandem axles are employed to carry the load.

b. A 1-ton standard 2-wheel trailer is illustrated in figure 75. The frame and body form an integral unit. The cross members underneath the body reinforce the floor board and form the rear section of the frame. The front end of the trailer body rests directly on a **V**-frame.

c. The landing gear wheel rotates on a shaft held by a yoke which is free to turn horizontally. The yoke is also pivoted to a landing gear casting so that the wheel may be raised or lowered. A removable pin can be placed in various holes of the yoke to hold the wheel at the desired height (fig. 76). The lunette (towing hook), mounted on top of the landing gear, is connected to the pintle hook of the towing motor vehicle. A short safety chain connects the trailer and the towing motor vehicle to prevent the trailer breaking loose. A tail lamp cable connects the trailer tail lamp to the towing motor vehicle electrical system. A simple mechanical parking brake is used when the trailer is uncoupled from the motor vehicle. It is operated by a hand lever (fig. 75).

d. A house trailer equipped with tandem axles is illustrated in figure 77. It is hitched to the towing vehicle by a standard SAE No. 2 ball and socket coupler (fig. 78). Its landing gear consists of an upright worm shaft with a small caster wheel clamped to its bottom end. When the trailer is being towed, the caster wheel is removed by loosening a thumbscrew and the worm shaft is raised by a hand crank.

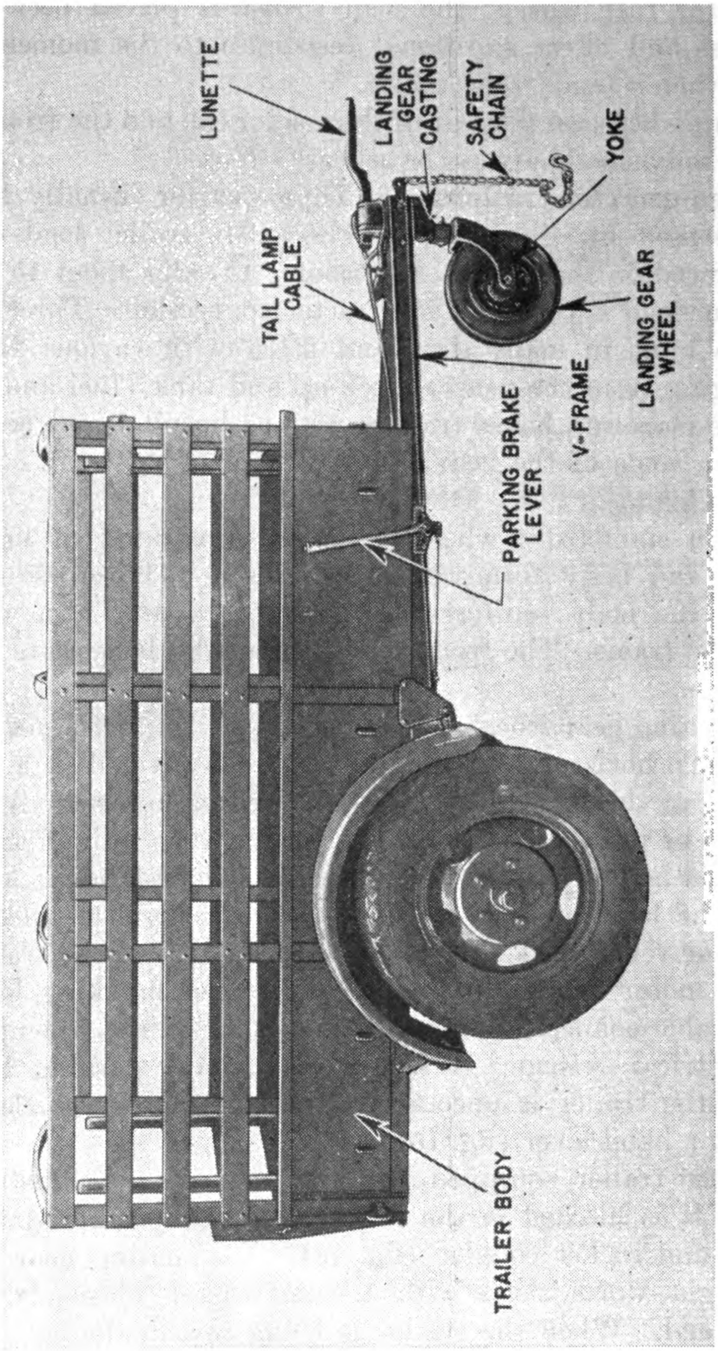

FIGURE 75.—Standard 1-ton 2-wheel trailer.

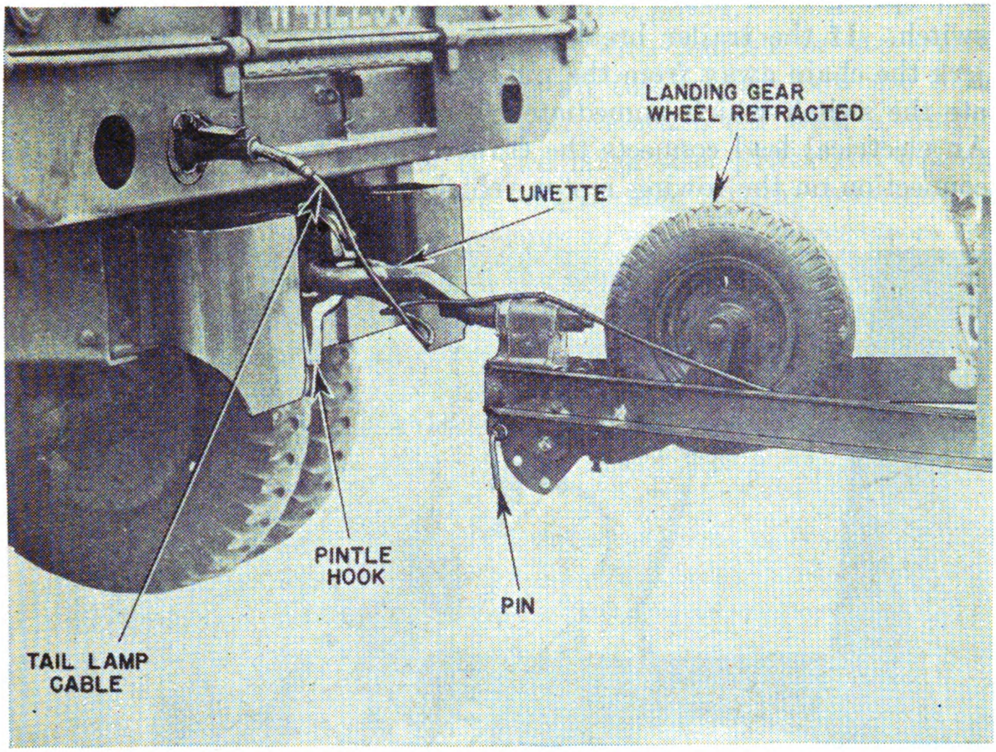

FIGURE 76.—Pintle hook connection to a 1-ton 2-wheel trailer.

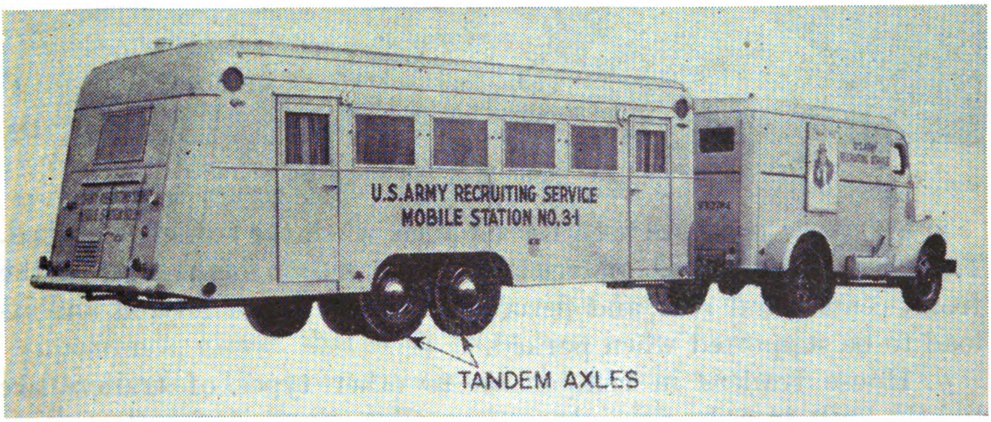

FIGURE 77.—House trailer with tandem axles.

e. Safety towing chains are connected between the trailer and the towing motor vehicle. Another safety feature is the short chain fastened by a snap hook to the towing motor vehicle and by an open loop spring hook which fits around a pin on the trailer brake safety switch. If the trailer breaks loose, the towing motor vehicle will jerk the chain away from the pin, which is thereby released to operate the switch which immediately applies the brakes of the trailer. An electrical lead connects the trailer brakes to the electrical brake connection on the towing motor vehicle.

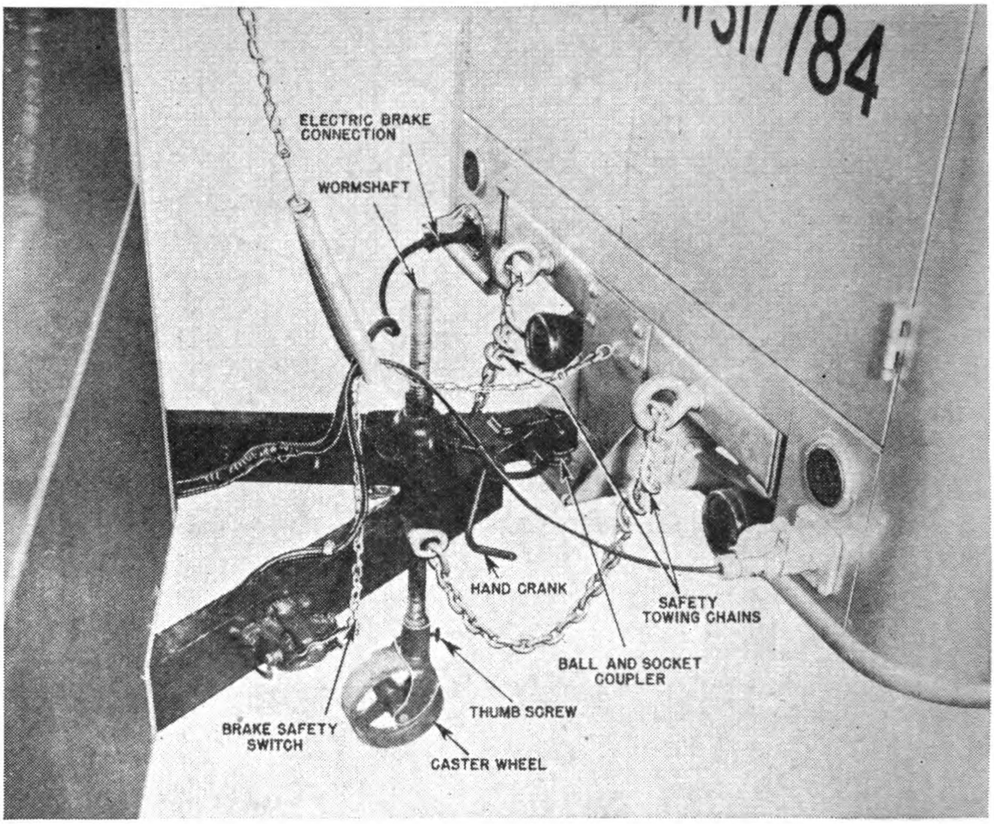

FIGURE 78.—Ball and socket connection to a house trailer.

f. Six screw jacks are used for supports when the trailer is parked. These jacks are placed underneath the frame on both sides at the front, center, and rear and permit the trailer to be leveled and its load to be supported when parked.

g. House trailers in comparison to other types of trailers are lightly built to reduce weight and to allow the use of soft springs. They are usually designed for use with soft spring passenger vehicles. If they are coupled to vehicles having stiff springs, the towing connection will be jarred considerably.

72. Full trailers.—*a.* Full trailers, which support their entire load, may be connected directly behind the towing motor vehicle, to a semitrailer, or to another full trailer. They are independent and fully contained vehicles without motive power.

b. Early full trailers were equipped with knuckle or Ackerman steering used on motor vehicles, but all full trailers now use fifth wheel steering. Many full trailers are constructed with a simple type of fifth wheel consisting of two large steel plates and a king pin. In a heavily loaded trailer, considerable binding between the fifth wheel plates hinders free steering, so when the driver steers the motor vehicle to the right or left, the binding fifth wheel resists the turning effort and tends to keep the motor vehicle traveling straight ahead. This is readily apparent to the driver when operating on slippery roads and makes steering not only difficult but dangerous. To overcome this, there is a tendency toward more refined fifth wheel designs that will turn freely under heavy loads by the use of bearings.

c. Full trailers may be classified as nonreversible, reversible, and converted semitrailers. A nonreversible full trailer can be towed and steered from one end only. Its frame (fig. 79) is supported by front and rear 2-wheel trucks which consist of a square frame made of channel sections containing the spring hangers. The rear truck is bolted to the trailer frame and forms an integral part of the chassis. A lower fifth wheel ring, mounted on top of the front truck, fits together with an upper fifth wheel ring attached underneath the front end of the trailer frame. The front truck, therefore, turns about the fifth wheel which allows the trailer to be steered. A towing tongue is pivoted to the front truck, and the other end contains a lunette which connects with the pintle hook of the towing vehicle. The trailer chassis illustrated in figure 79 is equipped with air-brake and electrical connections which are hooked up to the towing motor vehicle. A safety chain is provided to prevent the trailer from running away should the pintle hook connection break loose.

d. A reversible full trailer may be towed and steered from either end. It is similar to the nonreversible trailer in construction and appearance, except that both front and rear trucks are mounted by fifth wheels. The towing tongue is detachable and may be used with either truck. Both trucks are provided with locks so that one may be prevented from turning when the other is connected to the towing vehicle. This reversibility of towing ends increases the operating flexibility of the trailer.

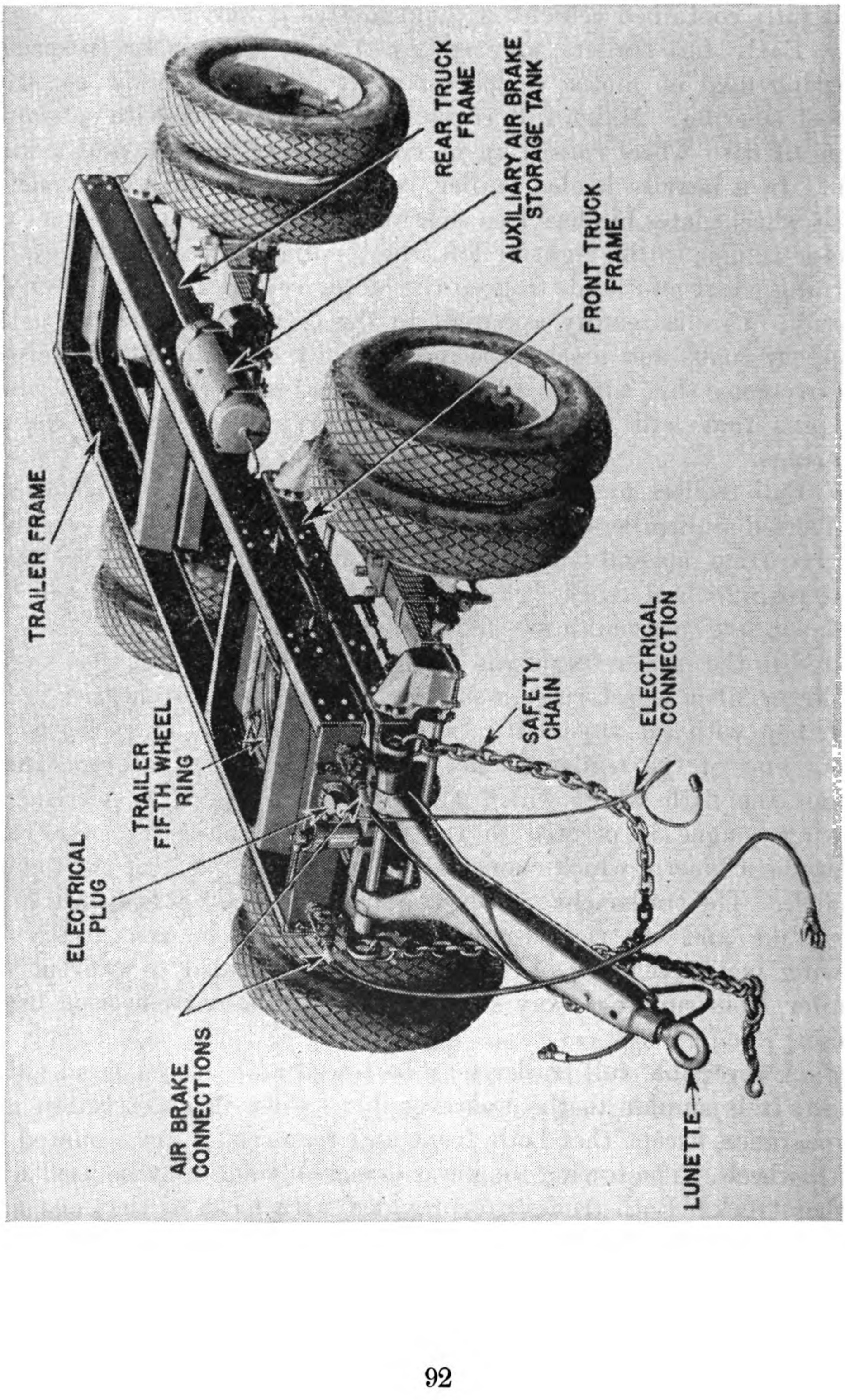

FIGURE 79.—Nonreversible full trailer chassis.

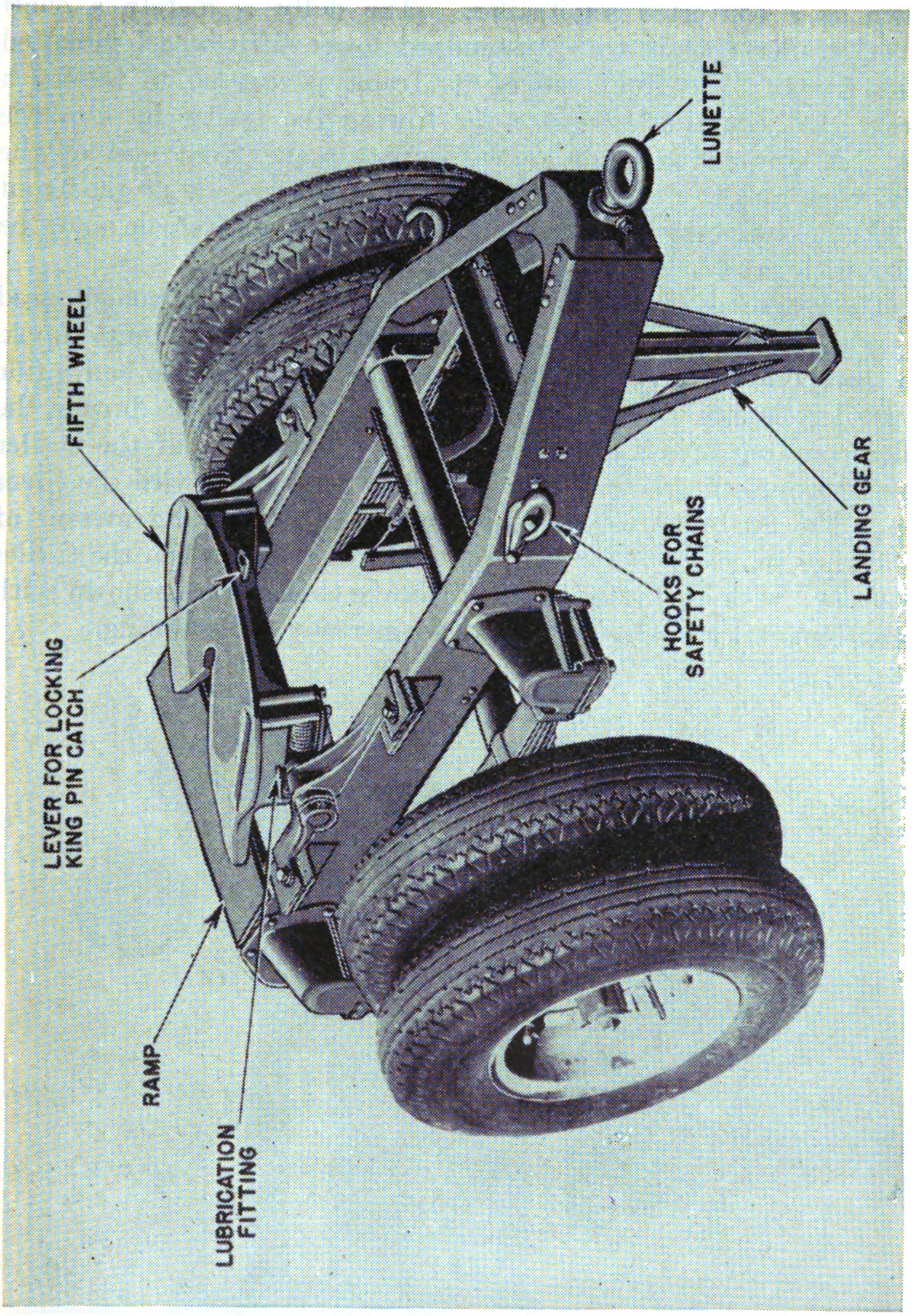

FIGURE 80.—Dolly for converting a semitrailer to a full trailer.

e. A semitrailer may be converted into a full trailer by mounting the fifth wheel on a dolly (fig. 80) and using the dolly in place of a tractor as the semitrailer front end support. Such a combination is known as a converted semitrailer. The dolly is merely a short 2-wheel trailer chassis with a standard lower fifth wheel mounted on its frame. The front end of its frame is tapered to receive a bracket that contains a lunette for towing the trailer by a pintle hook. A retractable landing gear supports the front end of the dolly when not in use. The open hooks on either side at the front end of the frame are used for joining the towing vehicle and the trailer with safety chains.

f. The rear end view (fig. 81) of a heavy duty motor vehicle used for towing three-quarter and full trailers illustrates the pintle hook. The rear bumpers protect the frame of the motor vehicle and guide the trailer lunette (towing hook) into the pintle hook during the trailer coupling operation. The electrical brake lead of the trailer is plugged into the electrical brake connection, shown with the cover open. The air-brake connections enable the air-braking system of the towing vehicle to be joined to that of the trailer when the trailer is equipped with air brakes. The air-brake connection is shown with its cap removed as it would appear when ready for coupling.

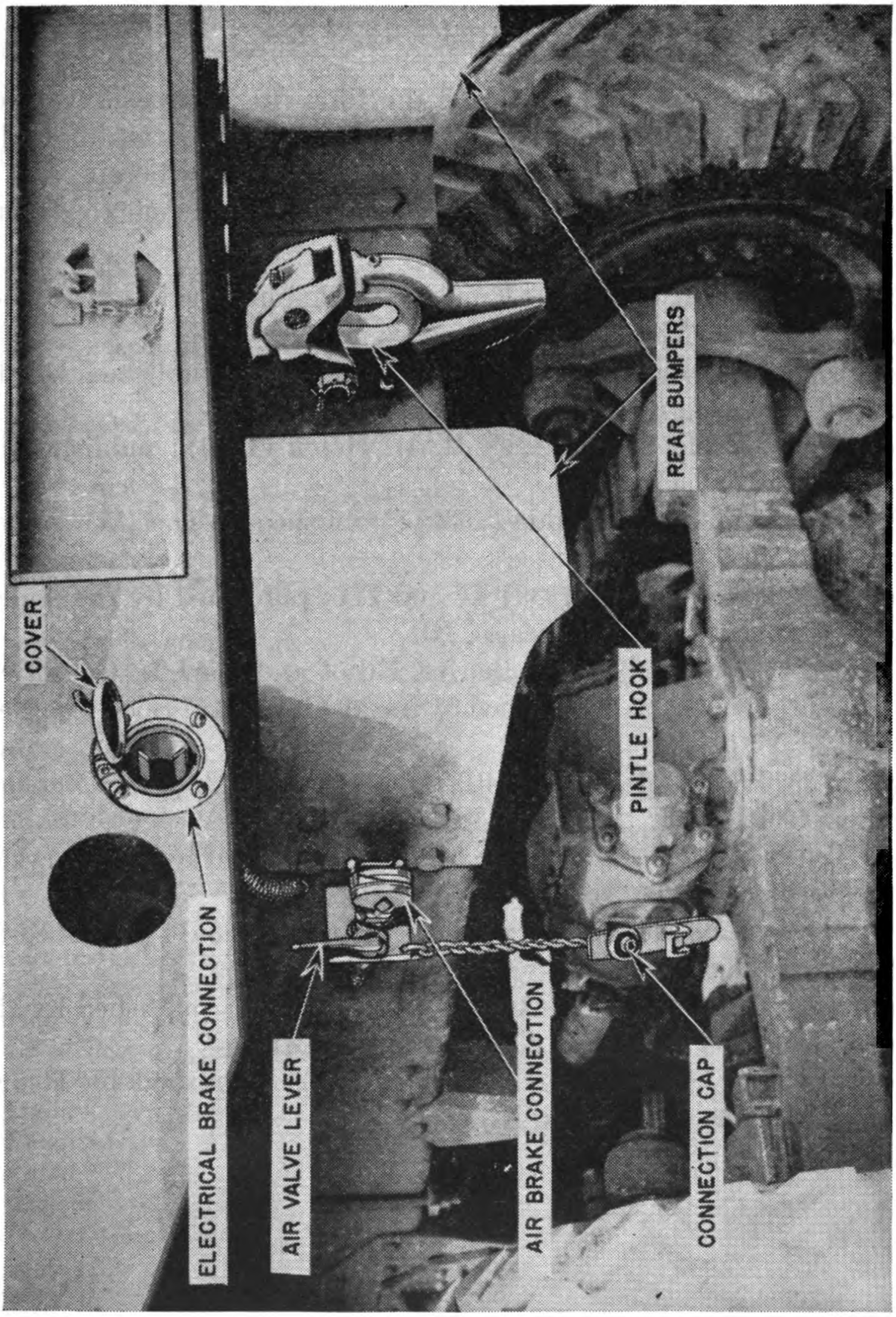

FIGURE 81.—Rear end of motor vehicle used for towing three-quarter and full trailers.

Appendix

LIST OF REFERENCES

In the preparation of this manual the following sources have been consulted for illustrations and text material. They contain more detailed information on motor vehicles than is contained herein, and it is suggested that it would be advantageous for the student to consult them as collateral reading.

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